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TRANSACTIONS

OF THE

Illinois State Academy of Science

FIFTH ANNUAL MEETING

BLOOMINGTON, ILL., FEB. 23 AND 24, 1912

VOLUME V

1912

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THE SECRETARY

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OFFICERS AND COMMITTEES FOR THE YEAR 1912-13.

President, HENRY CREW, Northwestern University, Evanston.
Vice-President, A. R. CROOK, State Museum of National History, Springfield.
Secretary, OTIS W. CALDWELL, University of Chicago, Chicago.
Treasurer, J. C. HESSLER, James Millikin University, Decatur.

The Council.

PRESIDENT, PAST PRESIDENT, VICE-PRESIDENT, SECRETARY, and TREASURER.

Publication Committee.

PRESIDENT, SECRETARY, and W. A. NOYES.

Membership Committee.

T. W. GALLOWAY, Chairman, Decatur.
MARION WELLER, De Kalb.
C. C. ADAMS, Urbana.
JOHN G. COULTER, Bloomington.
W. L. EIKENBERRY, Chicago.

Committee on Legislation or Agreements Which Would Set Apart Certain Waste Lands, Railway Rights of Way, Etc., for the Conservation, Propagation and Study of the Common Wild Flowering Plants.

H. S. PEPOON, Chairman, Chicago.
JOHN G. COULTER, Bloomington.
E. N. TRANSEAU, Charleston.

Committee on Legislation.

T. W. GALLOWAY, Chairman, Decatur.
OTIS W. CALDWELL, Chicago.
E. W. PAYNE, Springfield.
ELMER J. KNEALE, Springfield.

Committee on Calendar Reform.

T. C. CHAMBERLIN, Chairman, Chicago.
F. R. MOULTON, Chicago.
A. R. CROOK, Springfield.
C. G. HOPKINS, Urbana.
E. J. TOWNSEND, Urbana.

Committee to Arrange for the Editorship and the Publication of a Series to be Known as the State Academy Leaflets on High School Science.

T. J. MCCORMACK, Chairman, Principal, La Salle-Peru High School, La Salle.
WILLIAM C. BAGLEY, Director of Education, University of Illinois, Urbana.
JOHN G. COULTER, Illinois State Normal University, Bloomington.
H. S. PEPOON, Lake View High School, Chicago.
R. D. SALISBURY, University of Chicago, Chicago.

Committee on Ecological Survey.

STEPHEN A. FORBES, Chairman, University of Illinois, Urbana.
T. L. HANKINSON, Eastern Illinois State Normal, Charleston.
V. E. SHELFORD, University of Chicago, Chicago.
E. N. TRANSEAU, Eastern Illinois State Normal, Charleston.
CHARLES C. ADAMS, University of Illinois, Urbana.
FRANK C. BAKER, Chicago Academy of Sciences, Chicago.
H. S. PEPOON, Lake View High School, Chicago.

PAST OFFICERS OF THE ACADEMY.

1908.

President, T. C. CHAMBERLIN, University of Chicago.
Vice-President, HENRY CREW, Northwestern University.
Secretary, A. R. CROOK, State Museum of Natural History.
Treasurer, J. C. HESSLER, James Millikin University.

1909.

President, S. A. FORBES, University of Illinois.
Vice-President, JOHN M. COULTER, University of Chicago.
Secretary, A. R. CROOK, State Museum of Natural History.
Treasurer, J. C. HESSLER, James Millikin University.

1910.

President, JOHN M. COULTER, University of Chicago.
Vice-President, R. O. GRAHAM, Illinois Wesleyan University.
Secretary, A. R. CROOK, State Museum of Natural History.
Treasurer, J. C. HESSLER, James Millikin University.

1911.

President, W. A. NOYES, University of Illinois.
Vice-President, J. C. UDDEN, University of Texas.
Secretary, FRANK C. BAKER, Chicago Academy of Science.
Treasurer, J. C. HESSLER, James Millikin University.

CONSTITUTION AND BY-LAWS

Illinois Academy of Science

CONSTITUTION.

ARTICLE I. NAME.

This Society shall be known as THE ILLINOIS ACADEMY OF SCIENCE.

ARTICLE II. OBJECTS.

The objects of the Academy shall be the promotion of scientific research, the diffusion of scientific knowledge and scientific spirit, and the unification of the scientific interests of the State.

ARTICLE III. MEMBERS.

The membership of the Academy shall consist of *Active Members, Non-resident Members, Corresponding Members, Life Members, and Honorary Members.*

Active Members shall be persons who are interested in scientific work and are residents of the State of Illinois. Each active member shall pay an initiation fee of one dollar and an annual assessment of one dollar.

Non-resident Members shall be persons who have been members of the Academy but have removed from the State. Their duties and privileges shall be the same as those of active members except that they may not hold office.

Corresponding Members shall be such persons actively engaged in scientific research as shall be chosen by the Academy, their duties and privileges to be the same as those of active members, except that they may not hold office and shall be free from all dues.

Life Members shall be active or non-resident members who have paid fees to the amount of twenty dollars. They shall be free from further annual dues.

Honorary Members shall be persons who have rendered distinguished service to science and who are not residents of the State of Illinois. The number shall not exceed twenty at one time. They shall be free from all dues.

For election to any class of membership the candidate's name must be proposed by two members, be approved by a majority of the committee on membership, and receive the assent of three-fourths of the members voting.

All workers in science present at the organization meeting who sign the constitution, upon payment of their initiation fee and their annual dues for 1908 become charter members.

ARTICLE IV. OFFICERS.

The officers of the Academy shall consist of a President, a Vice-President, a Chairman of each section that may be organized, a Secretary, and a Treasurer. These officers shall be chosen by ballot on recommendation of a nominating committee, at an annual meeting, and shall hold office for one year or until their successors qualify.

They shall perform the duties usually pertaining to their respective offices.

It shall be one of the duties of the President to prepare an address which shall be delivered before the Academy at the annual meeting at which his term of office expires.

The Secretary shall have charge of all the books, collections, and material property belonging to the Academy.

ARTICLE V. COUNCIL.

The Council shall consist of the President, Vice-President, Chairman of each section, Secretary, Treasurer, and the president of the preceding year. To the Council shall be entrusted the management of the affairs of the Academy during the intervals between regular meetings.

ARTICLE VI. STANDING COMMITTEES.

The Standing Committees of the Academy shall be a Committee on Publication and a Committee on Membership.

The Committee on Publication shall consist of the President, the Secretary, and a third member chosen annually by the Academy.

The Committee on Membership shall consist of five members chosen annually by the Academy.

ARTICLE VII. MEETINGS.

The regular meetings of the Academy shall be held at such time and place as the Council may designate. Special meetings may be called by the Council and shall be called upon written request of twenty members.

ARTICLE VIII. PUBLICATION.

The regular publications of the Academy shall include the transactions of the Academy and such papers as are deemed suitable by the Committee on Publication.

All members shall receive gratis the current issues of the Academy.

ARTICLE IX. AFFILIATION.

The Academy may enter into such relations of affiliation with other organizations of appropriate character as may be recommended by the Council and be ordered by a three-fourths vote of the members present at any regular meeting.

ARTICLE X. AMENDMENTS.

This constitution may be amended by a three-fourths vote of the members present at an annual meeting, provided that notice of the desired change has been sent by the Secretary to all members at least twenty days before such meeting.

BY-LAWS.

I. The following shall be the regular order of business:

1. Call to order.
2. Reports of officers.
3. Reports of standing committees.
4. Election of members.
5. Reports of special committees.
6. Appointment of special committees.
7. Unfinished business.
8. New business.
9. Election of officers.
10. Program.

Adjournment.

II. No meeting of the Academy shall be held without thirty days' previous notice being sent by the Secretary to all members.

III. Fifteen members shall constitute a quorum of the Academy. A majority of the Council shall constitute a quorum of the Council.

IV. No bill against the Academy shall be paid without an order signed by the President and Secretary.

V. Members who shall allow their dues to remain unpaid for three years, having been annually notified of their arrearage by the Treasurer, shall have their names stricken from the roll.

VI. The Secretary shall have charge of the distribution, sale, and exchange of the published Transactions of the Academy, under such restrictions as may be imposed by the Council.

VII. The presiding officer shall at each annual meeting appoint a committee of three who shall examine and report in writing upon the account of the Treasurer.

VIII. No paper shall be entitled to a place on the program unless the manuscript or an abstract of the same shall have been previously delivered to the Secretary.

IX. These by-laws may be suspended by a three-fourths vote of the members present at any regular meeting.

Minutes of the Fifth Annual Meeting

BLOOMINGTON, ILLINOIS, FEBRUARY 23 AND 24, 1912.

SESSION OF FRIDAY, FEBRUARY 23, 2:00 P. M.

Address of Welcome, by Senator Frank Funk, President of the McLean County Academy of Science.

Reply by President W. A. Noyes.

REPORT OF THE SECRETARY.

MINUTES OF THE PREVIOUS MEETING.—The minutes of the fourth Annual Meeting, held at Chicago, February 17 and 18, 1911, have been published in Volume IV of the Transactions. The Council has held two meetings, one in Chicago, November 4, 1911, and one in Bloomington, February 23, 1912. The Council has considered all matters touching the policy of the Academy, including the time and place for the 1912 meeting, the program for the same, and certain matters regarding the form of Volume IV of the Transactions.

MEMBERSHIP.—Thirty-seven new members were elected at the Chicago meeting, 34 of whom completed membership by payment of dues. At the Chicago meeting the Secretary reported 371 names on the membership roll. The additions should, therefore, make a total of 408 members. Nine members have resigned, and 41 have been dropped for non-payment of fees, leaving a total of 358 names on the membership roll, or a net loss of 13 during the year. Thirty-five of the above failed to pay either annual dues or matriculation fee, and were dropped by limitation of three years, as provided in the constitution. It is evident that too great care cannot be used in proposing persons for membership in the Academy. No person should be nominated who has not individually expressed a desire to become a member.

We have lost by death one of our most valued members, Pro-

fessor Fred L. Charles, who died May 6, 1911. A memorial will be presented at this meeting.

PUBLICATIONS.—Volume IV has been sent to all members in good standing. Believing that a more systematic classification of the matter contained in the Transactions would make the volume more useful to those consulting its pages, the Secretary has, with the consent of the Council, departed somewhat from the beaten path, and the new volume appears in topical form, the business being concentrated in the fore part of the book, and the papers appearing under their respective classifications.

Calls for the Transactions by libraries, academies and museums continue to come in, as reported by the Secretary a year ago. It is, of course, impossible at present to carry on any system of exchange: first, because our treasury cannot bear the expense of the necessary postage; and, second, because there is no designated depository for the exchanges. The logical depositary would seem to be the State Museum, as, also, the logical Secretary should be the Curator of the State Museum.

ENLARGING THE FIELD OF THE ACADEMY.—The Secretary has carried on a vigorous campaign during the past three months in an endeavor to interest the scientific citizens of the State in the Academy. Circular letters to the number of 1,000 have been sent to all high schools, normal schools and other higher institutions of learning, and to many of the teachers of science and mathematics in these institutions. It is quite apparent that only by this and similar means can the Academy hope to become prominent in the scientific life of the State. If our teachers are constantly reminded of the value of being members of this institution, many of them will ultimately take advantage of the opportunity offered. To this end, upwards of 10,000 pieces of printed matter have been distributed to teachers, institutions, the newspapers and various individuals in the State who are, or ought to be, interested in the advancement of science. To successfully carry on this missionary work, a sufficient fund must be available to provide for the very large amount of clerical work incident to its accomplishment.

The Secretary expresses the hope that his successor may be a man of some leisure, who will keep the members in touch with the purposes of the Academy. It is confidently believed that the "slogan," 1,000 members, if kept persistently before the organization, will ultimately bring the Academy to this high-water mark of membership.

The Secretary wishes to express his appreciation of the assistance rendered by the Council as well as by many members of the Academy during his tenure of office.

Respectfully submitted,

FRANK C. BAKER,
Secretary.

REPORT OF THE TREASURER.

RECEIPTS.

Balance on hand, Feb. 17, 1911	$ 27.56
Membership dues	246.00
Life membership, one member	20.00
Initiation fees	46.00
Sales of Transactions	6.75
Total Receipts	$346.31

EXPENDITURES.

Balance paid on 1911 Transactions	$138.45
Expense of 1911 meeting	27.65
To J. C. Hessler, Treasurer, postage and printing	14.25
To Frank C. Baker, Secretary, for postage and printing	55.41
Cartage	6.28
Total Disbursements	$242.04
Balance on hand, Feb. 20, 1912	$104.27

(Signed) JOHN C. HESSLER,
Treasurer.

On motion, the Treasurer's report was accepted, and the President was instructed to appoint an Auditing Committee. The following Auditing Committee was appointed:

A. R. CROOK.
H. S. PEPOON.
W. S. STRODE.

REPORT OF THE MEMBERSHIP COMMITTEE.

In the absence of Professor H. C. Cowles, Mr. George D. Fuller reported for the Membership Committee. The names of

the following persons were presented, and upon motion and second, were elected to membership:

Abbott, Walter S., Nat. Hist. Bldg., University of Illinois, Urbana, Ill. (Entomology.)
Adams, Howard W., Normal, Ill. (Chemistry.)
Allen, Mary S., University of Illinois, Urbana, Ill. (Zoology and Botany.)
Barber, Fred D., Normal, Ill. (Physics.)
Barnard, Edith Ethel, 410 West Sixty-second St., Chicago, Ill. (Chemistry.)
Bassett, Herbert, Macomb, Ill. (Geography and Geology.)
Blount, Ralph E., 124 South Oak Park Ave., Oak Park, Ill.
Briscoe, C. F., 706 West California St., Urbana, Ill. (Bacteriology.)
Bullard, James D., Equality, Ill.
Coe, O. J., Ottawa, Ill. (Chemistry and Biology.)
Colyer, Frank H., Carbondale, Ill.
Cook, Nettie M., 630 South Seventh St., Springfield, Ill. (Botany.)
Grizell, Roy A., Nat. Hist. Bldg., University of Illinois, Urbana, Ill. (Entomology.)
Gutherlet, J. E., 308 Nat. Hist. Bldg., University of Illinois, Urbana, Ill. (Zoology.)
Funk, Frank H., Bloomington, Ill. (Corn Breeder.)
Glenn, P. A., 809 West Nevada St., Urbana, Ill. (Entomology.)
Goode, J. Paul, 6227 Kimbark Ave., Chicago, Ill. (Geography.)
Haupt, Arthur W., 1321 Norwood Ave., Chicago, Ill. (Botany.)
Hitch, C. Bruce, Bloomington, Ill. (Biology.)
Huber, W. H. P., Jacksonville, Ill. (Physiology.)
Huffington, H. L., Normal, Ill. (Biology.)
Hurter, Julius, Jr., 2346 South Tenth St., St. Louis, Mo. (Herpetology.)
Johnson, J. T., Kent, Ohio. (Biology annd Agriculture.)
Lipman, Mayer, 1607 West Sixty-third St., Chicago, Ill. (Physics.)
Lutes, Neil, 57 Broadway St., Freeport, Ill. (Chemistry.)
MacGillivray, A., University of Illinois, Urbana, Ill. (Entomology.)
Matthews, Albert P., University of Chicago, Chicago, Ill. (Physiological Chemistry.)
Matthews, Wm. C., Nat. Hist. Bldg., University of Illinois, Urbana, Ill. (Scientific Drawing.)
McNutt, Wade, Township High School, Highland Park, Ill. (Botany.)
Moffatt, Will S., 105 South La Salle St., Chicago, Ill. (Botany.)
Neiberger, Wm. E., Bloomington, Ill. (Eugenics.)
Newman, H. H., University of Chicago, Chicago. (Zoology.)
Perry, Edna M., Morton, Ill. (Zoology.)
Peterson, Alvah, University of Illinois, Urbana, Ill. (Entomology.)
Rentchler, Edna K., 305 North St., Normal, Ill. (Biology.)
Rich, John L., University of Illinois, Urbana, Ill. (Physiology.)
Ridgley, Douglas C., Normal, Ill. (Geography.)
Sampson, Homer C., University of Chicago, Chicago, Ill. (Botany.)
Scheffel, Earl Read, Urbana, Ill. (Geology.)
Spessard, Earl A., Y. M. C. A. Bldg., Aurora, Ill. (Biology.)
Tandy, M., Dallas City, Ill. (Biology.)

Van Alstine, E., Experiment Station, Urbana, Ill. (Chemistry.)
Wager, R. E., De Kalb, Ill. (Biology.)
White, Kessack O., State Geological Survey, Urbana, Ill. (Geology.)
Windsor, Mrs. P. L., 704 South Lincoln Ave., Urbana, Ill. (Entomology.)
Woodburn, Wm. L., Northwestern University, Evanston, Ill. (Botany.)

REPORT ON STATE MUSEUM.

In view of the interest which the State Academy of Science has taken in the State Museum, it is a pleasure to report that the outlook is bright for the erection of a new building to be known as the Educational Building, and planned with the intention of caring for the State Natural History Museum, the War Relics, State Historical Library, the State Library, the Department of Public Instruction and a Memorial Hall.

The last legislature appropriated $5,000 for defraying the expenses incident to securing plans, selecting site, etc. The State Architect is at present at work draughting preliminary plans for such a building.

The coming State legislature will doubtless be asked to appropriate money for the building. Various offers have been made by friends of the museum to give a building site for such a building in Springfield. The urgent need of such a building, especially from the view-point of the museum, is being more widely appreciated. Valuable materials are at present being but partly used. They are in some danger of destruction by fire. When the building is once completed the collections will be rapidly augmented and by process of elimination the more valuable will be retained and preserved.

With the securing of adequate and dignified quarters, a new era of usefulness and activity will be inaugurated and this institution, which for more than sixty years has been representing various scientific activities in this portion of the State, will enter upon a period of greater usefulness. A. R. CROOK.

REPORT OF COMMITTEE TO INFLUENCE LEGISLATION TO RESTRICT THE COLLECTION OF BIRDS AND EGGS TO INSTITUTIONS AND ACCREDITED INDIVIDUALS.

Your committee regrets to be compelled to report that it has accomplished nothing during the year. Press of other duties has so occupied the chairman that he has been unable to give the matter any attention. It has been observed, however, that, particularly on the outskirts of Chicago, the game laws are defied

regularly. In the newly opened road through the Budlong woods at Bowmanville, the chairman of this committee has encountered, on a Sunday afternoon, as many as a dozen boys and men with shotguns, sling-shots and air-guns, killing song birds. One such party was interviewed and a hunting license was produced. These men seemed surprised to know that this license did not permit them to shoot song birds as well as game birds. Some hunting of this sort has also been observed near Glencoe, Highland Park and other places along the north shore.

It is quite evident that without an adequate deputy warden force, it is practically impossible to prevent the killing of our song birds by these people. It also seems useless to ask for further legislation. The committee can only recommend the suggestions made by it at the Chicago meeting, and as it can be of no further use, asks that it be discharged.

FRANK C. BAKER, Chairman.
J. E. HESS.

On motion, duly seconded, the report was approved and the committee discharged.

A memorial to Professor Fred L. Charles, prepared by Professor E. L. Downing, was read by the Secretary.

The President appointed the following Nominating Committee:
U. S. GRANT.
FRANK SMITH.
T. L. HANKINSON.

DRAFT OF A REPORT OF THE COMMITTEE ON PUBLICATION OF A SERIES OF STATE ACADEMY LEAFLETS ON HIGH SCHOOL SCIENCE.

Your Committee on Publications for High School Science, pursuant to its instructions, offers the following report:

In view of the demand that high school students, in connection with their course in science, have opportunity to acquire information of local character upon topics which come within the general scope of these courses, your committee is of the opinion that a series of publications, designed for selection as supplementary reading in connection with these courses, and published under the control of the Academy, would be of educational service, and would be within the scope of the Academy's proper activities.

The following is offered as a list of suggested topics:

(1) The mineral resources of Illinois.
(2) The soil of Illinois.

(3) The topography of Illinois.
(4) The geology of Illinois.
(5) The native mammals of Illinois.
(6) The birds of Illinois.
(7) The fish of Illinois.
(8) The insects of Illinois.
(9) The trees of Illinois.
(10) The Spring flowering plants of Illinois—April and May.
(11) The Summer flowering plants of Illinois—June, July and August.
(12) The Fall flowering plants of Illinois—September.
(13) The edible fungi of Illinois.
(14) Plant breeding in Illinois.

As to plan of treatment, the committee reports that, in its opinion, the interest and comprehension of sixteen-year-old boys and girls should be determining factors. It is believed that a treatment so determined will attract rather than repel the reading of the publications by the general public. Following its instructions, the committee, if continued, will invite members of the Academy to prepare MSS. for these publications.

Under its authorization by the Academy, the committee has found assurance of an arrangement for the publication of this series which will relieve the Academy from financial responsibility, safeguard the use of its name, and insure to authors a royalty of at least 10 per cent.

However, no such arrangement will be finally concluded until some of the series are ready to print, which, in the opinion of the committee, will be at least a year from date. Report on this point is therefore deferred, in case the committee is continued, until the next meeting of the Academy.

The committee recommends its continuance, and, if continued, solicits coöperation from all members of the Academy.

Suggestions as to topics and authorship will be welcomed.

Respectfully submitted,

T. J. McCormack.
William C. Bagley.
R. D. Salisbury.
H. S. Pepoon.
J. G. Coulter.

The report was adopted and the committee continued.

The presentation and discussion of scientific papers occupied the remainder of the afternoon.

SESSION OF FRIDAY, FEBRUARY 23, 6:00 P. M.

6:00-7:00—Bloomington Club; social hour.

7:00—Banquet (80 persons present).

8:30—Presidential address, "The Electron Theory," by President W. A. Noyes.

SESSION OF SATURDAY, FEBRUARY 24, 9:00 A. M.

Symposium on Conservation.

Professor E. O. Jordan was not able to be present, owing to a sudden outbreak of typhoid fever at Rockford, which necessitated his immediate presence. Brief remarks on Water Pollution by President Noyes.

The other addresses were given in the sequences as printed.

The Nomination Committee presented the following list of candidates:

Henry Crew, President.

A. R. Crook, Vice-President.

Otis W. Caldwell, Secretary.

J. C. Hessler, Treasurer.

Membership of Publication Committee—W. A. Noyes.

Membership Committee—T. W. Galloway, Marion Weller, C. C. Adams, John G. Coulter, W. L. Eikenberry.

REPORT OF THE AUDITING COMMITTEE.

We, the committee appointed by the Chairman of the Illinois State Academy of Science to audit the accounts of the Treasurer, John C. Hessler, find the same to be correct and true.

(Signed) A. R. CROOK, Chairman.
W. S. STRODE.
H. S. PEPOON.

Dr. A. R. Crook moved that a committee of physicists and mathematicians be appointed to consider the reform of the calendar. Seconded and carried. The following committee was appointed: Prof. T. C. Chamberlin, Prof. F. R. Moulton, Dr. A. R. Crook, Dr. C. G. Hopkins, Dean E. J. Townsend.

On motion of Dr. C. C. Adams, the chair was instructed to appoint a committee of five members on legislation. The following committee was appointed: Dr. T. W. Galloway, Chairman; Dr. O. W. Caldwell; Mr. E. W. Payne, President State Bank,

Springfield, Ill.; Mr. Elmer J. Kneale, office of State Register, Springfield, Ill.

Mr. J. W. De Wolf moved that a letter be sent to all members, requesting their opinion relative to the kind of program favored for the annual meetings. Unanimously carried.

Mr. Worallo Whitney moved that a circular letter be sent to high schools, informing the teachers of the purposes of the Academy and of the possibilities of the work in science. Seconded and carried.

Dr. H. S. Pepoon moved that a committee of three be appointed to secure legislation which would set apart certain waste lands for the propagation and study of the common wild flowering plants. Seconded and carried. The names and membership of the committee are as follows:

Committee on Conserving Wild Flowering Plants on Waste Lands, Right of Way of Railroads, Etc.—Dr. H. S. Pepoon, Dr. John G. Coulter, Dr. E. N. Transeau.

SESSION OF SATURDAY, FEBRUARY 24, 2:00 P. M.

Report of committee appointed to investigate the relations of the pure and applied sciences in high schools.

Discussed by Baker, Burrill, Galloway, Coulter, Caldwell, and President Noyes.

The Secretary reported the following recommendations from the Council:

1. That the Illinois State Museum at Springfield be the designated depositary for the surplus stock of Transactions, and that the exchanges derived from the Transactions be also deposited in the library of the State Museum.
2. That the necessary expenses of the Treasurer and Secretary, while in attendance at the annual meetings, be borne by the treasury of the Academy.

On motion, duly seconded, the above recommendations were approved and adopted by the Academy.

Dr. Crook presented resolutions as follows:

1. Thanks to local committee, Wesleyan University, and J. F. Toldte and R. O. Murphy for lantern and operation.
2. Thanks to Secretary.

Dr. S. A. Forbes gave a verbal report for the Committee on Ecological Survey.

The remainder of the afternoon was occupied with further scientific papers.

On motion, duly seconded, the fourth annual meeting of the Illinois Academy of Science adjourned.

The President's Address

THE ELECTRON THEORY.

W. A. Noyes.

The first fairly comprehensive theory of chemical combination which bears some relation to modern views was proposed in a rather informal way by Lavoisier. Shortly after Priestly had discovered "dephlogistigated air," in 1774, the great French chemist came to recognize very clearly the fundamental part which the newly discovered element plays in nature. Finding that it is an essential element in the acids formed by the combustion of sulphur, phosphorus, nitrogen and carbon, he called it oxygen—the acid-former—a name still appropriate, though I think that most chemists to-day do not recognize how appropriate, so clearly as did the chemists who lived a century ago. Lavoisier also recognized that oxygen combines with metals to form what were then called metallic calxes, and with the assistance of De Morveau and others a nomenclature was introduced which was based on the view that the oxides of the non-metallic elements, called acids, combine with the oxides of the metallic elements, which had been called calxes, to form salts. This nomenclature still clings to us in such names as sulphate of potash. The thought expressed in this nomenclature, that there is a dual nature in the salts, furnished a very natural basis from which the electrochemical theory of Davy and Berzelius was easily developed. According to this theory, the atoms of the elements have two electrical poles, one positive and one negative, and the properties of the element depend upon whether the one or the other of these poles contains more electricity, chemical combination depending on the discharge of two poles of opposite signs when the atoms of two elements come together, the heat of combination being caused by this discharge. The resulting compound may still have an excess of positive or

negative electricity, and so a positive oxide like that of potassium may combine with a negative oxide such as that of sulphur to form a salt. This theory dominated chemistry for nearly half a century.

The next important step toward an insight into the nature of chemical combination was the discovery of Faraday, in 1833, that the same current passing through a succession of electrolytes liberates equivalent quantities of elements or radicals at the electrodes immersed in the different solutions. This discovery points very clearly to a definite unit quantity of electricity which is directly connected with those primary units of matter which we call atoms. It is not a unit of energy, since the energy absorbed in the decomposition of the different electrolytes is different. The fundamental conception which we are forced to, was stated very clearly by Helmhotz in his Faraday lecture, in 1881: "If we accept the hypothesis that elementary substances are composed of atoms, we cannot avoid the conclusion that electricity, positive as well as negative, is divided into definite elementary portions, which behave like atoms of electricity." Maxwell, too, spoke of a "molecule" of electricity in 1873, but evidently had little sympathy with such an idea. This idea is quite different from that in the theory of Berzelius, who considered that differences in affinity were caused by differences in the quantity of electricity in different atoms. The next advance, therefore, seems rather a step backward than forward, as it consisted in the overthrow and complete abandonment of the old electrochemical theory. In that theory chlorine was always negative and hydrogen was always positive in their compounds. But Dumas showed that three derivatives of acetic acid could be prepared in which one, two or three[1] atoms of the positive hydrogen could be replaced by one, two or three atoms of the negative chlorine, and yet the resulting compounds were monobasic acids resembling acetic acid in their salts and in their decompositions. In his attempts to explain these and other compounds on the basis of the electrochemical theory, Berzelius found himself more and more in conflict with well established facts of organic chemistry, and in spite of his tremendous authority as one of the greatest chemists of his time, the chemical world gradually abandoned the dualistic point of view and accepted a unitary conception of chemical compounds. Then, beginning in the fifties, there came the period of the rapid development of the theories of valence and of structural organic

[1] In the formulas used by Dumas, two, four or six atoms.

chemistry. During this period, which lasts, with very little change, to the present time, the attempt to connect the forces which hold the atoms in combination with electrical forces in any definite way was almost completely abandoned. It is true that the terms "positive" and "negative" have been frequently used throughout the period, but they have been used in a wholly vague and indefinite way, with no real thought of electrical properties in the groups.

As so often happens, the beginning of a return to an electrical theory of combination came from the study of phenomena in a different and, as it seemed at the time, wholly unrelated field. During the late seventies, Crookes busied himself with the study of electrical discharge through highly rarefied gases. The phenomena which he discovered were so strange and startling that he spoke freely of a "fourth state" of matter. The physicists and chemists of the time were disposed to look on the expression as somewhat sensational, but the event has shown that he was nearer right than his critics. The phenomena of most interest to us are those of the discharge from the cathode, or negative pole, through a tube in which the pressure of the residual gas has been reduced to one-millionth of an atmosphere. Under such conditions rays are shot out in straight lines perpendicular to the surface of the cathode and when they impinge on the glass opposite they produce a beautiful green fluorescence and give rise to the X-rays, though those rays were not discovered till some fifteen years later. Crookes showed that this "radiant matter," as he called it, almost with the vision of a prophet, travels straight across the tube, irrespective of the location of the anode. He showed that an opaque object in its path will cast a sharp shadow on the fluorescent glass; he showed that if it strikes the vanes on one side of a little wheel suspended in its path the wheel will rotate, and he showed that it can be deflected by a magnet. He found, too, that this radiant matter came always from the negative pole, never from the positive. He had discovered a stream of electrons, but the world had to wait some fifteen years before the X-rays emanating from the fluorescent glass were discovered, and nearly twenty years before the real properties of the electrons were established.

Meanwhile, during the eighties, the ionization theory of Arrhenius was proposed, and with Ostwald as its Nestor, gained rapidly in favor until it has become to-day the only logical basis which we have for the accurate discussion of the properties of solutions.

The development of the theory has demonstrated almost as certainly that atoms or groups of atoms carrying one or more units of an electrical charge exist independently in a solution of an electrolyte, as the study of gases has demonstrated that independent molecules of nitrogen peroxide exist in the gas which consists of a mixture of nitrogen peroxide, NO_2, and nitrogen tetroxide, N_2O_4. What becomes of these charges when the ions reunite, is a question which has scarcely been raised till recently.

From the idea that the reactions between electrolytes in solution take place between ions bearing electrical charges, it is a very simple and natural step to the thought that other reactions may occur in a similar manner. An application of this thought to the reactions of the elements soon leads to the view that the molecules of elementary substances may sometimes separate into positive and negative atoms. This conclusion was, perhaps, first expressed by Van't Hoff in 1895, in an attempt to explain the formation of ozone during the slow oxidation of phosphorus.[1] Similar views were expressed by myself[2] in 1901, and were quickly followed by a statement from Professor Stieglitz that he had presented the same idea some time before at the University of Chicago. Three years later Professor Abegg, of Breslau, published a remarkable paper in which he developed the idea of the electrical polarity of the atoms in considerable detail, and proposed his theory of normal valences and of contra valences, the sum of the two kinds of valences for any given atom being eight. Thus a nitrogen atom may develop toward hydrogen three negative, normal valances or toward oxygen it may assume five, positive, contra valences. In this paper Abegg points out for the first time a probable connection between his theory and the theory of electrons.

Lavoisier and many others of the earlier chemists seem to have considered an atomic or molecular constitution of matter as probable, but the first definite basis for an atomic theory was, of course, laid by Dalton's discovery of the laws of combining weights and of miltiple proportion, in the early days of the nineteenth century. He did not discover the law of constant proportion, and the evidence which he gave for the law of miltiple proportion was exceedingly crude from the quantitative standpoint; indeed, there is to-day, as far as I know, only a single case for which the law has been demonstrated with an accuracy of one part in a thousand, and the determinations for that single

[1] Z. physik. Chemie, *16*, 411 (1895).
[2] J. Am. Chem. Soc., *23*, 460 (1901).
[3] Ibid., *23*, 797 (1901).

case are recent. For a genuine experimental basis we must treat the law as a corollary of the law of combining weights. We all remember that Dalton was not successful in selecting true atomic weights, and while both Avogadro and Amprere suggested a correct basis for the selection very shortly after Dalton's first publication, their suggestion did not meet with approval. So it happened that for the first half of the nineteenth century chemists generally were confused about the atomic weights which they should use, and many of them became skeptical about any possibility of certain choice among the miltiples which might be selected and were disposed to content themselves with a system of equivalents. In the late fifties, Cannizaro, who died only two years ago in Italy, rescued the law of Avogadro from oblivion and contributed very much to the general acceptance of a rational system of atomic weights. A decade later the discovery of the periodic system by Mendeleef and Lothar Meyer confirmed in a most brilliant manner the truth and value of the principles on which the new table of atomic weights was based. At the same time the periodic system pointed, irresistibly, toward some common substratum or ultimate material from which the atoms have been built up or into which they might be disintegrated, but this remained for thirty years and longer only a tantalizing suggestion. Meanwhile the insight which the development of organic chemistry gave into the structure of molecules forced upon organic chemists, at least, a growing conviction of the actual existence of atoms and molecules. In spite of this, the close of the nineteenth century saw the rise of an important school of chemistry, under the lead of Ostwald, which apparently wished to abandon the atomic theory altogether and would have been glad to express all of the facts of chemistry in terms of energy and in the language of mathematical equations. The discoveries of the last decade seem to have convinced even the leader of this school, and I think that to-day we may accept atoms and molecules as actual existing entities with almost the same certainty with which we accept the existence of the sun, moon and planets. With the atomic theory goes, almost of necessity, the kinetic theory of gases. Indeed, some of the most convincing demonstrations of the truth of the atomic theory have come along the lines of the kinetic theory. I might say, in passing, that the second law of thermodynamics, that the entropy of a system always tends to increase, presupposes, almost of necessity, an atomic constitution of matter.

As Helmholtz pointed out clearly in 1881, the acceptance of the atomic theory forces upon us the recognition of a unit quantity of electricity which is just as definite as the atom itself and which Helmholtz very properly said "behaves like an atom of electricity." But the physicists of that day and for long afterwards were accustomed to think of electricity from the standpoint of energy, and the suggestion remained unheeded; indeed, it is very doubtful if Helmholtz himself grasped its full significance.

In 1897 Professor J. J. Thomson took up again the study of the cathode rays in a Crookes tube. These rays had then acquired an extraordinary interest from their use in the production of X-rays. Professor Thomson devised a very ingenious experiment in which he deflected the cathode rays into an insulated hollow vessel by an electromagnet. Knowing the capacity of the vessel, he could determine the quantity of electricity carried into it by the electrons in a given time. He also arranged to have the electrons fall on a thermocouple of known heat capacity, and determined the energy developed on stopping them. From the data obtained he calculated that the velocity of the particles was of the order of ten thousand miles a second, or even as high as 1/10 the velocity of light. The quantity of electricity carried by the particles was found to be very considerable in proportion to the heat energy shown by the thermocouple. These facts seemed to allow of only two alternatives: either the mass of the particles is extremely small or each particle must carry an enormous charge of electricity. Further experiments confirmed the choice of the first of these possibilities, and physicists are generally agreed that the mass of the electron is about one eighteen hundredth part of the mass of a hydrogen atom. Physicists are not altogether agreed, however, as to whether this electromagnetic mass is the same in nature as the mass of an atom which may be measured by reference to the force of gravity. If it is affected by gravity, an electron having a velocity of 10,000 kilometers a second would fall toward the earth possibly two millimeters in flying 800 kilometers, say, as far as from here to Pittsburgh. The difficulty of preparing a straight, evacuated tube of that length is evidently rather great, and we shall probably have to wait some time for experimental evidence on this point. The question has become one of unusual speculative interest in the light of the discussion by J. J. Thomson and the measurements of Kaufmann and Bucherer, which seem to show that the mass of the electron is wholly dependent on the velocity with which it moves.

I will not attempt to discuss how the theory of electrons explains the varied phenomena of electricity and magnetism. Before passing on to its application in chemistry, I will speak of only two or three of the conclusions which have been reached. The electron may be defined as an atom of negative electricity and the current through a metallic conductor seems to be an actual flow of electrons in one direction. In the vacuum tube the electrons or cathode rays fly also only in one direction, but if the cathode is perforated and a residual gas is present, positively charged atoms or molecules may be shot in the opposite direction, of course at a much lower velocity because of their enormously greater mass. These atoms form the canal rays of Goldstein. In electrolytes the electrons no longer move independently as in metallic conductors, but attach themselves to the so-called negative atoms or groups and move slowly in one direction, while the positive atoms or groups—those which have lost an electron—move in the opposite direction. We have long known the metals as the positive portion of electrolytes. It is only recently that this property has been connected with the electrical conductivity of metals. According to the electron theory, a metallic atom forms the positive portion of an electrolyte because it has lost one or more electrons. A metallic wire conducts electricity because it allows the electrons in or associated with the atoms to slip along easily from one atom to another, since the electrons easily escape from the individual atom.

Several authors have discussed the nature of chemical combination in the light of the electron theory. The most elaborate discussion is that of J. J. Thomson.[1] His fundamental assumption is that atoms are composed of a group of electrons within a uniform sphere of positively electrified matter. A single electron would go to the center of such a sphere. Two electrons, owing to their mutual repulsion, would be in equilibrium at a distance from each other equal to the radius of the sphere. Three electrons would form an equilateral triangle, four a tetrahedron, six an octohedron; but Professor Thomson says that he has been unable to solve the general problem for n electrons distributed in a sphere. He gives, however, a rather remarkable solution on the supposition that the electrons are situated in a plane. In that case they will arrange themselves in concentric rings and for a given number of electrons there is only a single stable arrangement. Further than this, with a given number in the exterior

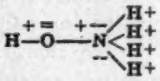
[1] Philosophical Magazine, March, 1904.

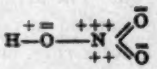
ring, the number which can be placed within is limited by two extremes. The most suggestive case of this kind is that with 20 electrons in the outer ring. The total number of electrons with such an outer ring can never be less than 59 and can not exceed 67. This might be supposed to correspond to a group of nine elements of the periodic system from helium to neon or from neon to argon. The arrangement with 59 electrons, if it lost one, would be compelled to rearrange to a form having only 19 electrons in the outer ring, but owing to the positive charge acquired by the loss of the electron, it would immediately acquire another and go back to its original form. Such an element would have a valence of 0 for a positive charge, and Professor Thomson suggests that this would correspond to such an element as helium or neon. But he goes on to say that the element would have a valency of 8 for a negative charge, which does not, of course, correspond to the properties of the zero group. A group of 60 electrons might lose one electron and acquire a permanent positive charge of one valence, which would correspond to such an element as lithium or sodium. It ought, however, to be capable of gaining 7 electrons; that is, it should have a valency of seven for a negative charge. Here, again, the facts do not correspond to the theory. It seems evident that the theory needs to be supplemented by some explanation why electropositive elements lose electrons but do not readily take them up, while it would seem that the electronegative elements can do both. The facts seem to be connected with the properties of metals as conductors and of non-metals as non-conductors.

Lorenz in his explanation of the Zeeman effect seems to assume that the electrons revolve around a nucleus of matter having a positive charge. It seems possible that the idea of Lorenz is true for metals, that of Thomson for non-metals.

Whichever theory is accepted, the notion that atoms may acquire positive or negative charges by the loss or gain of an electron and that the charged atom may then attract another atom bearing a charge of the opposite sign seems likely to be a fruitful one. I will give an illustration of possible application to well-known facts. An atom of nitrogen may receive four electrons from four hydrogen atoms if at the same time it gives one to the oxygen atom of a hydroxyl group. But the hydroxyl group is loosely held by the nitrogen atom with its four electrons and the compound ionizes and reacts as though consisting of ammonium and hydroxyl. One atom of nitrogen may also give five electrons to three oxygen atoms in forming nitric acid. Here the nitrogen

atom, which has become strongly positive, holds the oxygen of the hydroxyl group firmly, but the positive hydrogen is repelled. And so nitric acid ionizes and reacts as though composed of hydrogen and nitrate ions. This will be clearer from an inspection of the following formulas:





The *facts* referred to have, of course, been long known, but as far as I know, this is the first attempt at a rational explanation.

In the development of the electron theory, the intimate connection between electrical phenomena and light, foreshadowed by Maxwell's electromagnetic theory, more than forty years ago, becomes more and more apparent. The spectrum lines are, of course, to be traced back to the motion of electrons, and it is not an impossible dream that these lines may enable us to decipher the structure of the atoms—that the atoms have a complex structure no one can doubt in the light of radiochemistry.

The color of compounds and the rotation of the plane of polarization are also connected with the electrons. Dr. Fry, of Cincinnati, has shown how the theory may help to a solution of intricate phases of the benzene problem.[1] It seems very certain that it is a theory with which we must reckon for some time to come. In studying it we still feel keenly the need of some more fundamental explanation. The elementary idea of attraction is just as difficult to accept when applied to atoms bearing positive and negative charges as when applied to the heavenly bodies at distances of millions of millions of miles. In both cases the thoughtful mind finds it impossible to believe in action at a distance without some medium or mechanism to connect them. And so I can not do better than to close with the words of Professor Thomson: "The theory is not an ultimate one; its object is physical rather than metaphysical. From the point of view of the physicist, a theory of matter is a policy rather than a creed. Its object is to connect or coördinate apparently diverse phenomena, and above all to suggest, stimulate and direct experiment. It ought to furnish a compass which, if followed, will lead the explorer further and further into unexplored regions. Whether these regions will be barren or fertile, experience alone will decide; but, at any rate, one who is guided in this way will travel onward in a definite direction and will not wander aimlessly to and fro."

[1] Z. physik. Chem., 76, 385, 398, 591.

Symposium on Conservation

CONSERVATION OF THE HUMAN RACE.

J. N. HURTY,

State Health Commissioner of Indiana.

High authority says we are only 50 per cent efficient; that we live out less than one-half the natural duration of life; that we consume twice as much food as is needed to maintain efficient life; that we waste as much as we use, and that one-half of all human beings born either die before reaching maturity or fall into the defective, delinquent or dependent classes. In these facts we find reasons why we waste the major portion of all our resources and call it development. In these facts we find reasons for the existence of robber taxation and predatory business. For, a people who waste themselves will, of course, waste their natural resources. Therefore, the first, the most important, the fundamental, conservation is the conservation of human vitality. A people who cannot be brought to a realization of the fact that they lead only half lives, and who, realizing, will not mend, will show the nations to come what fools the present mortals were.

LENGTH OF LIFE.

Length of life is a resultant of strength. Honor thy father and thy mother that thy days may be long in the land the Lord thy God giveth thee. It is an honor and it is a strength for a nation to have a low sickness and a low death rate, with their consequent lengthened average duration of life. In India the average length of life is twenty-five years; in the United States, forty; in England, forty; in Germany, forty-three, and in Sweden, forty-five. The natural duration is one hundred years. Metchnikoff, after thirty years of study of disease and death, says only a very few die natural deaths; most of mankind commit suicide; that is, most people do not know how, or will not, conserve their vitality, and thus results a greater or less period of disability and inefficiency, with premature death. Nature does no fooling; she has her laws, and they are enforced up to the handle.

VITAL ASSETS.

Comparison of vital and physical assets as measured by earning power shows that the vital are three to five times the physical.

The facts show that there is as great room for improvement in our vital resources as in our lands, water, minerals and forests; and furthermore, this improvement must come first, for through human life only is natural conservation possible. The dead past may bury the dead, but living and strong men, not the weakly and sickly, must do the work of conservation. And the future belongs to that nation which has the highest virility.

ILLNESS.

From our vital statistics, which constitutes the bookkeeping of humanity, we learn that fully 150,000 people in Illinois are sick at all times, 35,000 of whom are consumptives. Not less than half of this is preventable, and three-fourths may be prevented by strong effort. Eighteen experts in various diseases as well as vital statisticians have contributed data on the ratio of preventability of the ninety different causes of death into which mortality may be classified. From this data it is found that fifteen years at least could be at once added to the average lifetime by practically applying the science of preventing disease. More than half of this additional life would come from the prevention of tuberculosis, typhoid fever and five other diseases, the prevention of which could be accomplished by purer air, purer water and purer milk. Let the business men, who are in the saddle and who run our affairs, thoroughly consider this. They surely know that diseases and premature death are drags to business. Fifteen more years of life to each citizen means an enormous increase in the strength and happiness of the people.

Minor Ailments must be thoroughly considered in any steps toward the conservation of vitality. They are far more common and farther reaching than is generally realized. They are chiefly functional disorders, such as of the intestinal canal, heart, nerves, liver, kidneys, etc. These disorders are gateways to the more serious disorders. Those who neglect colds, or what seem to be colds, will prepare the tissues of the respiratory tract for pneumonia and consumption.

Benjamin Franklin, wise and practical, successful as merchant, scientist and statesman, said: "The having of colds is a great drawback. I notice when I have one my efficiency is greatly decreased. Thought, judgment and understanding are clouded. Furthermore, I notice that colds follow excess in eating and drinking and the much breathing of bad air. They are quite unnecessary." The losses due to mistakes in business and in the

general conduct of life on account of minor ailments cannot be estimated except perhaps as time lost. A study of the matter shows that the time lost cannot be less than four days annually to each supposedly well man. Applying this to the wage-earners of Illinois, counting one wage-earner to each five people, making 650,000 in all, and this State has to pocket an annual loss of 2,600,000 days, or 7,150 years. This is certainly a prodigious loss to suffer because of minor ailments, all of which can practically be avoided by proper public and private hygiene.

Neurasthenia, so common in the United States, is one of the most serious and insidious introductions to grave disorders, which may be due to depraved nutrition, to needless worry, or failure to have adequate recreation.

SCHOOL HYGIENE.

In conserving vitality, the child must have physical defects removed as far as possible, then must be brought up amidst healthful surroundings and itself trained in all that conserves health. Indiana has already taken steps in this direction. The sixty-seventh General Assembly ordained that the schoolhouses hereafter built shall be sanitary in all particulars. This means that waste of money and waste of child strength and happiness shall cease in this fair State, so far as this one matter goes. The same assembly has given permission to school authorities to institute medical inspection of school children, that they may be relieved of morbid physical conditions which cause pain, inefficiency, illness and early death. It was a marked forward step to grant this privilege, but it was a mistake in favor of loss of vitality not to make this care of children compulsory. Physical strength is the fundamental requirement for the making of children into educated and moral citizens. There is now a world-wide movement, led by Switzerland and heathen Japan, to save children and make them strong. A Japanese physician traveling in this country said: "We have relatively fewer short graves in our cemeteries." The intelligence of a community could be accurately measured by determining its relative number of short graves. Youth is the time to serve the Lord. We must train the body in youth as well as the mind, or the opportunity to conserve vitality is largely lost. A far better business scheme than securing factories would be for the business men to turn their attention to the conservation of human vitality. The returns would be immense; failure to score in such an effort is impossible.

SYPHILIS AND GONORRHEA.

Hygiene has been permitted to extinguish cholera and yellow fever, and by the grace of private benefaction it will soon banish hookworm disease, which now incapacitates 2,000,000 people. And may God hasten the business men to permit hygiene to banish those twin leprosies, syphilis and gonorrhea, which are important factors in the causation of insanity, crime and pauperism, and which so fearfully wreck the lives of so many innocent women and children, as well as wrecking the lives of the guilty. Syphilis and gonorrhea are responsible for the existence of a large proportion of defectives of various kinds which fill our institutions. Let hygiene drive these plagues away, and Illinois, instead of building more insane hospitals, could donate one or two now existent to educational use of some kind.

SAVING VITALITY.

Strength, endurance and fatigue are the three great elements to be considered in conserving life. The measure of strength is the force a muscle can exert once; the measure of endurance is the number of times it can repeat an exertion. Fatigue is caused by fatigue poisons, which must be removed from the body during rest, principally during sleep.

Anything, therefore, which reduces strength and lessens endurance and prevents removal of fatigue is inimical to vitality conservation.

SCIENCE OF LIVING.

The science of living begins at the mouth. Barring the taking of drugs, as a man eats and digests his foods, so he is. Owing to drug-taking and errors in human feeding, disease is latent in man at all times. Only a few escape sickness and pain and die natural deaths. This is not as nature would have it. Josh Billings, recovering from heart trouble caused by tobacco, said: "Nature made us all right; we make fools of ourselves." Other drugs which are of almost universal use, and which affect heart, nerves or efficient elimination, are coffee, tea, spices, cocaine, morphine, chloral and alcohol. All of these are drugs, and all are poisons, and all more or less disturb the vital functions, reducing vitality and efficiency.

Any departure from unstimulated nutrition works harm. Stimulated nutrition is unnatural, and perforce is opposed to strength.

Immoderate eating—feasting and gluttony—reduce vitality and induce disease with its consequent inefficiency. A very old adage says: "Most men dig their graves with their teeth." The old-time writer of this was working for the conservation of human vitality. Immoderate amounts of nitrogenous foods, exemplified in white of egg and lean meats, cause auto-intoxication. They do this by undergoing putrefaction in the digestive tract, thus making toxins, which in turn, being absorbed into the body, cause the following train of ills, which results in loss of vitality and efficiency. Some of the auto-intoxication ills are: biliousness, coated tongue, foul breath, clammy hands and feet, dry, lusterless hair, putty complexion, dulled hearing, dulled vision, dulled taste, dulled smell, loss of memory, loss of continuous thought and attention, headaches, vertigo, dyspepsia, loss of weight, loss of strength, rheumatism, insomnia, fugitive pains and aches, irregular heart, shortness of breath, brittle nails, dry, harsh skin, cancer, and premature old age of the doddering and slobbering kind.

Until we learn and practically apply this science of living, we cannot attain over 50 or 60 per cent efficiency and must continue to live lives of sickness, pain and disease, and die before the natural duration of life has one-half expired; and if this does not hinder and delay the conservation of natural resources, nothing will.

Over-fatigue is a cause of loss of vitality. The present working day, from a physiological standpoint, is too long. Overwork, better expressed by the term over-fatigue, starts a vicious circle leading to the craving of means for deadening fatigue, thus inducing drug habits and drunkenness.

Experiments in reducing the length of the working day show a great improvement in the physical and mental efficiency of laborers and result in an increased output sufficient to pay the difference. However, the great justification of the shorter day is found in the interests of the race and nation, not the employer. Public safety requires, in order to avoid railway collisions and other accidents, the prevention of long hours; lack of sleep and undue fatigue is quite as great as the waste from serious illness. A typical succession of events is: first, fatigue, then "colds," then tuberculosis, then death. In order to prevent in the beginning this increasing line of destructive agencies, undue fatigue must be prevented.

HEREDITY.

Vitality rests upon inherited qualities. A child born of weak parents, those parents having received their weakness by inheritance, will itself be weak in the same way. Idiots breed idiots. Whatever improvement the child may enjoy must rest upon its inherited foundations. If a child inherits brown eyes, they must stay brown; but inherited weak sight may be improved to a greater or less degree. Two forces, therefore, control vitality—namely, conditions preceding birth and conditions during life. In other words, the foundations of vitality are wholly inherited, and may be cultivated to the degree the inherited foundations will permit.

A perfectly sound physical and mental inheritance is rare, and is the greatest of all assets. The highest development of a nation will begin when the human law conforms to God's law of development and parenthood is denied the defectives. A defective has no right to burden society with other defectives. Prisons and asylums are now sufficiently numerous, and it is evidence of defectiveness of the masses to conduct our affairs so as to necessitate their increase. My State now has five great insane asylums, each representing about one million dollars, and there are enough insane in jails, poorhouses and in homes to fill another one. Our population increased 7.6 per cent in the last decade, and insanity increased 29 per cent.

To go along in the future as in the past, permitting—even fostering—the production of the hereditary insane, of the hereditary criminals, of the hereditary idiot and feeble-minded, and then building great palaces in parks to care for them, will mean we have not the sense necessary for the proper conduct of our affairs.

HYGIENE.

We must look to hygiene, the science of health, to conserve human vitality. The term includes every force necessary to prevent disease, to increase strength and endurance, and to prevent the production of the unfit.

The ponderous and oppressively costly courts have been grinding for centuries, and crime increases. Punishment and fear of punishment restrain evil-doing, but do not eradicate the tendency to evil. This and other defects we must, as far as possible, breed out of the race, and science can find a valid answer for

every objection which obstructionists can raise. Fostering insanity, crime and imbecility is not evidence of understanding and of high ability.[1]

The divisions of hygiene are: Federal, State, Municipal, Institutional, School, Domiciliary, and Personal.

Hygiene not only makes for greater physical strength and endurance but it makes for greater moral strength. It is the essence of charity, kindliness, patience and truth.

When, through hygiene, defectives are no longer propagated; when we understand that preventable sickness is immoral; when simplicity and frugality of living is achieved, voluntary sickness, voluntary celibacy and voluntary childlessness will become discreditable, and premature deaths will disappear before temperance and sanified homes.

THE NATIVE ANIMAL RESOURCES OF THE STATE.

STEPHEN A. FORBES.

The native animals of this State were once its most important economic asset, furnishing perhaps the larger and certainly the more highly valued part of the food, and all the clothing, of its inhabitants, and almost the total mass, also, of its merchantable products. Now, however, they are reduced to such economic insignificance that few would be found to object seriously, on merely economic grounds, to a fiat of extermination to be issued against our whole native fauna, if the injurious might go with the beneficial species. We would cheerfully sacrifice what is left to us of our native fish and game if we might pile upon the same altar the vast destructive host of what we commonly call our insect enemies, together with the gophers, mice and moles of the fields and the owls and the hawks of the air.

Permit me to try to sketch rapidly the nature, the process and the causes of this transformation, in the hope that we may see to what extent it has been, and perhaps still is, normal and helpful to us, and to what extent, if at all, it has gone, or is likely to go, too far in any part of its movement—at what points, if at all, it may be improved upon for our purposes, or may perhaps be profitably arrested or reversed.

[1] To devise punishments for offenses, and then deliberately produce criminals who will certainly commit those offenses, is an expression of public feeble-mindedness.

The chief pressing and universal requirements of our aborigines were food, clothing, shelter, instruments of transportation, and articles of barter, the last especially important after white traders began to come among them. Our native Illinoisans were mixed feeders, like the North American Indians generally, but with a marked preference for animal food. We have no data sufficiently detailed for an intelligent judgment of the relative importance to be assigned to the corn, beans and squashes, on the one hand, raised by their women on their bottom-land fields, and to the products of their hunting, on the other; but our Indians were clearly hunting tribes—governed in their movements to and fro by the migrations of their game—rather than truly sedentary agricultural people like those farther to the south. Hunting and fishing were their principal economic pursuits, and their mental and physical development was most strongly influenced by their contact with the animals of their environment, which they must outwit or master or outrun in order to gain a living for themselves and their families. Their fuel was, of course, mainly wood, with buffalo chips, perhaps, as an occasional convenience. Their clothing was almost wholly made from the skins of animals, with buckskin as the chief material. Their boats and their permanent shelters were mainly of forest products, the frames of their huts of wood and the covering of mats woven from strips of bark; but the objects of their barter, particularly with the whites, were almost wholly furs and skins obtained by hunting and trapping.

Notwithstanding this steady draft upon the native animal resources of the country, the original number of our Indian inhabitants—estimated at something like 200,000 for all North America east of the Mississippi River—was too small to affect in any overwhelming way the general system of animal life, which would apparently have gone on but little changed if they had been suddenly exterminated. In Illinois they probably influenced the fauna of the State more powerfully by their prairie fires than in any other way.

The first appearance of the white man made little or no alteration in these relations, for the discoverers and explorers of our territory necessarily lived much as the Indians did; and the hunters and traders and earliest squatters, who were in part the successors of the explorers, were similarly dependent on the untamed products of the country—especially so upon its animals, which gave them not only the major part of their food but also

the greater part of the materials of their trade. Barter for furs, as we all know, was almost the sole business of the first business men of the State, and their food was probably even more largely animal than that of the Indians among whom they lived, since they killed their own game, but rarely planted any crop. An employee of the American Fur Company, stationed, in 1819, at an Illinois River post near the present site of Hennepin, says, in his recently published autobiography:

"Our roasted meat . . . was placed in the large wooden bowl on the table, and each one helped himself by cutting off with his knife and fingers as much as he desired. Usually we had nothing else on the table except honey. The wild turkey was used as a substitute for bread, and when eaten with fat venison, coon or bear, is more delicious than any roast can be. One of our luxuries, which was reserved for special occasions, was corn soup, and this was always acceptable. . . . From the ponds we gathered the seeds of the lotus, which we used for coffee, our ever-filled honey-trough furnishing the sweetening. Our supply of salt and pepper was rather limited, and these were used only on special occasions."*

It was not, in fact, until the farm-maker and the town-builder appeared on the scene, bringing in a much denser population than could live on the mere surplus product of our native plants and animals—the bare interest on our capital in plant and animal resources—that this primitive system of maintenance broke down. When too heavily drawn upon, the animals of the State began to yield a smaller instead of a larger product, because an excessive demand had the effect to reduce the number of producers; and a substitution of more productive resources became a necessity. The white man being substituted in rapidly increasing numbers for the scanty and stationary Indian population, wheat, oats and corn and the tame meadow grasses were substituted for the wild plants of the prairie turf, and to some extent for the growths of the forest; beef cattle, pigs and sheep were substituted for buffalo, bear and deer; and to these were added milch cows, oxen, horses and mules, not represented functionally by anything in the native fauna. Chickens, geese and ducks were substituted for the prairie-hens, pigeons and wild waterfowl; and for the preservation of all these valuable but defenseless animals, wolves and bears and all the other large carnivora were virtually exterminated.

*"The Autobiography of Gurdon Saltonstall Hubbard." The Lakeside Press, Chicago, 1911, p. 57.

The result has been, of course, an immensely greater product of far more valuable and more readily available resources, sufficient for a population many thousand times greater and more exacting than any which formerly existed here. The whole process has evidently been a perfectly natural and inevitable one—as much so as the flow of the tide in the wake of the revolving moon—and immensely advantageous, also, from every point of view except that of the inadequate, incompetent and ill-adapted population which it has reduced or suppressed. These native populations were not, however, all unfit for survival under the dominant influence of civilized man, and such as were unfit were not equally so. Some were promptly and completely extinguished, others slowly and partially so; some remained undisturbed by our interference, and some continue more numerous and more prosperous to-day than ever before, because the new conditions established are more favorable to them than were the old. Wolves and wildcats, for example, were soon virtually suppressed as unmitigated nuisances, and buffalo, deer and the prairie hen went as early, or even earlier, because they could not be profitably domesticated, and could not breed, unprotected in the wild, fast enough to make good their losses. The fishes in our larger streams diminished slowly in numbers—if, indeed, taken as a whole, they diminished at all, until recent reclamation projects began to drain and cultivate their spawning places and feeding grounds—and the smaller plants and animals of our waters, upon which the fishes depend for food, were, until quite lately, at least as abundant as they ever were. No native insect species has disappeared from our borders, and several of the most abundant and voracious of them—the most injurious, consequently, to our interests—find a far better food in our cultivated crops, and, in our agriculture and horticulture, a system of management far better adapted to their needs, than was the original system which we have displaced. Our resident game birds would all have been gone long ago if it had not been for the restraints of law put upon the activities of the hunter, and the migrant game species are sadly reduced in numbers; but the smaller seed eaters, fruit eaters and insect eaters among birds are, I believe, more numerous now, on the whole, than they were in the days of the prairie, the Indian and the buffalo.

All the various processes of destruction, maintenance, protection, substitution and new introduction to which this state of our fauna is due are still in active operation; and they are in

great measure as automatic and unreflecting, in respect to the motives behind them, as they ever were. Most men still act towards the wild life of the State precisely as if they were wild animals themselves, and seem to think no more of its future than does the hawk or the hungry wolf; but the *State*, as such, has recognized, of late, its responsibility to future generations, and is beginning to shape the course of events with forethought and intelligence in the permanent interests of its people. It is for this Academy to assist this movement, both by helping to popularize it and by contributing to its direction.

To give you an outline sketch of present conditions and tendencies over the whole field of zoölogy would take more time than I have been allotted, and I can only summarize the facts and make brief suggestions of policy concerning our fishes, game animals and insectivorous birds.

The waters of the State have been much longer unaffected, and remain much less affected still, by human activities than any other parts of our area. Each of our rivers or lakes is yet, indeed, a piece of the primitive wilderness, which no one pretends to cultivate or to hold as such with a view to cultivation. It may have been greatly affected indirectly, in respect to its fitness as a home for plants and animals, by our various operations on its banks or in its neighborhood; but the picture of life presented by its waters, its bottom and its shores is still in its main features that of the days before the white man in America. In respect to the natural resources offered us by its plants and animals, we are lingering in the pioneer or squatter stage of progress, and we may still see belated illustrations of methods of appropriation in operation there, much too crude to be tolerated in any other field.

Almost nothing aquatic has been wholly exterminated, even the larger mammals and birds—the beaver, the otter, the swan, wild geese, pelicans and cranes—still remaining in small numbers in sufficiently favorable situations. Fishes, turtles, minks, muskrats, frogs and river mussels or clams remain as almost the only immediately valuable animal products of the waters of the State, and these are, on the whole, quite as valuable as they ever were.

No native fish has completely disappeared from our territory, although several useful species have been greatly reduced in numbers within recent years. The only comprehensive statistical reports upon the interior fisheries of the country have been made

by the United States Fish Commission and the United States Census Bureau for 1894, 1899 and 1908. The second of these census years came just before the opening of the Chicago Drainage Canal in 1900, and the last one eight years after that revolutionary event, and nine years after the introduction of the European carp into the public waters of this State. The two occurrences of critical importance within the period covered by these reports are thus the opening of the drainage canal and an enormous increase in the numbers of carp.

The drainage canal, by increasing the average depth of the Illinois River between two and a half and three feet, and greatly enlarging the area and lengthening the period of overflow, has greatly extended the lateral range of the fishes of the river, especially in its middle course, enlarging at the same time their breeding grounds and feeding grounds, and bringing into the stream a tremendous load of sewage from Chicago and its suburbs. The first effect of such an enlargement of the aquatic area must be to scatter the normal fish population more widely and make it less accessible to the fisherman. On the other hand, the enlargement of their breeding and feeding grounds doubtless tends to an increase in the numbers of fishes by the better provision made for the survival of the young; while the final effect of sewage contamination upon the inhabitants of the stream will turn upon the manner in which these organic contributions are gradually worked up, through the ascending series of the plants and animals of the water, the margin, and the bottom, to bring them within the reach of fishes in some form of life available for their food.

The most interesting result I have obtained from an analysis and comparison of the three census reports referred to is an indication that the numbers of our native bottom-feeding fishes are being gradually diminished as an indirect consequence of the rapid and enormous multiplication of the introduced carp. This fish has now become so abundant, and commercially so important, that it is the main object of our commercial fisheries. The yield of the Illinois River, for example, was $412,000 worth of carp in 1908, while the value of all the other fishes taken from the stream that year was only $309,000. In 1894 the carp yielded, in Illinois, 860,000 pounds; five years later, nearly 10 million pounds; and nine years later still, 21,642,000 pounds—the *value* of this Illinois yield increasing in this period 27⅓ times, or from $21,000 to $574,000. The native coarse fish, on the other hand, which, like the carp, search the bottom of the stream for their food, yielded approxi-

mately 9½ million pounds in 1894, nearly 6¾ million pounds in 1899, and about 6¼ million pounds in 1908,—a loss of 29 per cent between 1894 and 1899, and of 7 per cent between 1899 and 1908.

The number of men employed during this period increased from 1,653 to 4,359, about 2⅔ times as many being engaged in fishing in 1908 as in 1894; and the investment in fishing equipment increased in the same period more than three and one-half times—from $156,000 to $553,000. That is, while fishing operations increased from two and one-half times to three and one-half times, and the product of European carp was multiplied over twenty-five times, the product of the bottom-feeding food fishes native in these waters fell off 29 per cent during the period before the drainage canal was opened—a period coincident with that of the most rapid multiplication of the carp. This can only mean, it seems to me, that under the stimulus of fishing operations due to the rapidly growing importance of this exotic fish, the number of native fishes of similar habit is being rapidly reduced. The yield of buffalo was, in 1908, 52 per cent of that for 1894; that of the fresh-water drum, or sheepshead, was 60 per cent; of eels, 74 per cent; of suckers, 67 per cent. The catfish yield diminished 19 per cent for the first five years, and then increased 30 per cent for the next nine,—a net gain of 4 per cent, comparing 1908 with 1894.

Furthermore, the principal game fishes have also fallen off materially in yield, with the exception of the black bass, whose product increased about 6 per cent for each year of the first period and 36 per cent each year of the last. The sunfishes and the croppies, on the other hand, increased their product an average of 28 per cent for each of the first five years and of 26 per cent for each year of the last nine. Their rate of reproduction seems sufficient, under the new conditions, to hold them up under the new drain of excessive fishing for carp. These species all breed in shallow water and feed mainly on crustaceans, insect larvæ, and other minor forms of animal life, and their breeding grounds and feeding grounds have been enormously extended by the rise in river levels and the greater expansion and longer continuance of the overflow consequent upon the opening of the canal. Moreover, most of them select nesting places, makes nests, and care for their eggs and young, and hence bring to maturity a comparatively large percentage of each new generation.

Another important fact obtained from a comparison of our census data is the enormous and destructive increase of mussel-

fishing in this State. The Illinois product of mussel-shells in 1894 was 24 tons, in 1899 it was 2,500 tons, and in 1908 it was 20,000 tons, with a value during the latter year of $184,000 for shells and $170,000 for pearls and slugs. This must, of course, result in the prompt destruction of the mussel population of our streams.

To summarize these statements in a sentence, it is plain that the clam fisheries of the State are being rapidly exhausted, and that the European carp is, with the aid of the fishermen, rapidly swamping and smothering out several of our native food fishes, both coarse and fine, excepting, however, the sunfishes and the black bass. This seems due not to direct competition between the native and the imported species, but to human interference under the economic motive. We have here a substitution process at work, like that of our pioneer agriculture, but differing from that in the fact that it has been unintentional and hitherto unnoticed. If these present tendencies continue we shall apparently have, in time, our larger and more important fishing streams producing little but carp, sunfishes, black bass, gizzard-shad, dogfish, and gars, with even the catfishes engaged in a somewhat doubtful struggle for existence.

Several additional dangers now threaten the Illinois River, much the most important of our productive waters. It may become overloaded with sewage from Chicago and from the cities on its banks; the establishment of manufactories along its course or on its contributing waters may befoul it with chemical wastes poisonous to fish or injurious to their food supply, a process which has completely depopulated many streams in the eastern states, and which some of these states are now seeking to correct, at great expense and trouble, by legal restrictions and administrative control. Our recent work shows that the productivity of a stream is dependent upon the extent and condition of its backwaters and the period of its overflow, a fact which makes drainage district operations on the river bottoms a menace to its productiveness. The same is true of measures for straightening the stream and confining it to its channel, such as are likely to be necessitated if the Illinois is to become at any time a great artery of commerce.

These conditions require prompt, vigorous and intelligent rectification and control if we are to preserve and improve the natural resources represented in our lakes and streams—measures quite beyond the reach of any power except that of the State. If time permitted, I should be pleased to enter upon a discussion of

various future policies necessary to this end, but I must pass it now with the general remark that the most important measures which should be taken at the present time are, in my judgment, the protection of our waters against injurious contaminations, especially from gas works and certain kinds of manufactories; and the preservation, intelligent care, and complete control of selected breeding grounds and feeding grounds of our most important fishes, to be acquired, held, and developed as permanent reservations by the State. The State Fish Commission has, in fact, made a beginning in this direction, and has lately secured a long-time lease of Matanzas Lake, in the Illinois bottoms, which it is preparing to use as a breeding station. It also seeks to maintain the supply of our more desirable fishes by hatchery operations, and by collecting young fishes from isolated overflow ponds and returning them to waters in which they can survive.

Whether the insectivorous birds of the State are of sufficient importance to be taken into serious account in cataloging our economic resources, is a question which can not be answered with the definiteness and precision which we are accustomed to expect as the outcome of anything worthy to be called strictly scientific investigation. The value of the services of birds depends upon the *kinds* of their food and the *ratios* of its various elements; upon the *variations* in their food and feeding habits as coördinated with differences of season, geographical situation, and ecological circumstance; upon the *amounts* of food eaten by birds of various species at various ages and under the various conditions of their activities; and upon the *numbers* of the various kinds of birds engaged in the economic services with which they are to be credited. The problem of the food of any bird is thus highly complex, and its primary data are so variable that even final conclusions, however broadly based, must be put in the form of approximate estimates and contingent probabilities, amounting to scarcely more than expressions of an enlightened personal judgment.

The quantities of food taken by birds, young and old, can not well be stated in terms of definite values, or masses, or numbers of individual objects eaten. Nevertheless, accumulated observations, continuous for days at a time, on the activities of parent birds of various species in feeding their young, furnish conclusive evidence of the fact that a family of nestlings may devour and assimilate a truly surprising amount of insect food; and the rapidity of growth and the high rate of physiological activity of birds as a class give theoretical support to statements which might

otherwise seem incredibly exaggerated. The insects eaten by an insectivorous bird are evidently to be numbered in hundreds per day; and the weed-seeds eaten by a seed eater, in thousands.

With respect to the number of birds inhabiting any extensive area, the only systematic work attempted is that done in recent years by the Natural History Survey of this State. Thanks to this work, we now know something of the numbers of birds of various species in our area in different situations and at different seasons of the year. Time will not permit more than a brief reference to this matter, especially as our data have not yet been completely studied. I have generalized them, however, to the effect that, taking the State as a whole and the year as a unit, our bird population averages something over a bird per acre for the open area of the State—excluding, that is, forests and other similar tracts on which accurate counting of birds is impracticable. This population varies greatly, of course, in density, according to the character and vegetable covering of the surface. Pastures contain, on the whole, more birds than any other open surface, and corn fields the fewest of all. The tendency of birds to concentrate where their food is especially abundant, and even to change their habits temporarily, in order to take advantage of an unusual profusion of certain elements of their food, greatly increases their economic value, since it makes them most efficient where their efficiency is most important. Nevertheless, the very fact that insectivorous birds thrive best when insects are most numerous must lead us to doubt that nature has really committed the blunder of producing birds in such numbers, and endowing them with appetites so vigorous, as to keep the natural sources of their own food supply much below the line of the highest possible productivity.

That birds are economically useful, scarcely admits of serious question, but the ultimate value of their services can scarcely be guessed at intelligently until much more work has been done on the problem. In the meantime, there are abundant reasons, both economic and esthetic, for their protection, and to this end the most important pending measure is the passage of national laws forbidding the destruction of migrant species—an interest which I would like to have this Academy promote by a resolution favoring the passage of the Anthony bill, now under consideration in the national House of Representatives.

The fur-bearing mammals of the State are by no means so nearly extinct as most of us would be likely to suppose. The

mink and the muskrat remain in numbers still to figure in the United States census reports, the Illinois yield of mink furs being valued by the last census at $6,000 per annum, and the muskrat at $14,000. Even the otter has been reported to me by the deputy game wardens of Illinois[1] as still present in twenty-three counties, mainly in the southern half of the State, although a few reports come from the more northern counties bordering upon the Illinois and the Mississippi. The beaver is reported from four Ohio River counties; but the marten and the fisher have long been extinct in this State.

Among the larger mammals we have lost the elk, the buffalo, the panther or puma, and the black bear. The Virginia deer is still sometimes seen in southern Illinois, but hunters there believe that it crosses the river from Missouri, and does not breed within our limits. Its occasional occurrence in several of the more northern counties is to be attributed to its escape from parks. Both the prairie-wolf and the timber-wolf are widely distributed in very small numbers, one or both of these having been lately seen, according to the deputy wardens, in at least forty-three Illinois counties. Lynxes and wildcats have been lately reported from fourteen counties, seven of which are in extreme southern Illinois. Red and gray foxes are found by the game wardens in forty counties; and the raccoon and the opossum are common enough to be hunted occasionally. The woodchuck holds its own fairly well in the northern part of the State, and the swamp-hare may yet be found in our southern cypress swamps. The common rabbit is, of course, everywhere abundant. The fox-squirrel and the gray squirrel still live in our woods in scanty numbers, and the red squirrel or chickaree occurs at present in Iroquois County, where, however, it was specially introduced. The badger is undoubtedly to be found in northern Illinois; and skunks and weasels are, of course, still with us, although in smaller numbers than formerly.

The really significant game of the State is virtually reduced, however, to wild ducks, shore-birds, prairie-hens, quail, and the plebeian rabbit. Quail are found, in fact, in every county; and prairie-hens—thanks to our protective laws—are now to be seen in at least seventy-four counties, so abundantly in some that farm-

[1] The data here given concerning the larger fur-bearing animals of the State I owe in great measure to the courtesy of Hon. John A. Wheeler, State Game Commissioner, who was kind enough to obtain for my use, and at my request, information from his deputy wardens throughout the State as to the present animal life of their respective counties. Reports have thus come to me, since this paper was begun, from eighty-five of the hundred and two counties of the State.

ers are beginning to protest against their further increase because of the amount of grain which they devour. Wild turkeys occasionally occur in the more broken, wooded country, but too rarely to offer any considerable inducement to the hunter. In short, with the exception of the elk, buffalo, and bear, we have the larger forms of the wild mammalian animals of the State, and most of the game birds also, still present to an extent such that we need only to protect them strictly to have them back again in any numbers which can find food, shelter, and safety in their present environment. That this must at best fall far short of their original abundance is shown by the results of the recent protection of the prairie-hen. The very country in which it was formerly most numerous—that is, the open prairie—is now least favorable to it because of the agricultural operations, which disturb and destroy it during its breeding season.

Time has failed me, in the preparation of this brief paper, to enter into particulars concerning the work of the state commissions now engaged in maintaining and protecting the valuable wild animals of the State and in improving the composition of our fauna by the introduction of exotic species. These are the State Fish Commission and the State Game Commission, to which reference has already been made. The biennial reports of the former, some fifteen in number, give a sufficient account of their work. The State Game Commissioner has not yet published regular reports of his operations, but they are described in a brief but comprehensive illustrated article printed in the Arbor and Bird Day Circular issued by the State Superintendent of Public Instruction in 1909.

CONSERVATION OF OUR FORESTS.

HENRY C. COWLES.

Many might think it strange that forest conservation should have a place of importance in the "Prairie State." And statistics might be cited to bear out the contention that for us the topic is one of small significance. Illinois is accustomed to occupy among our States a place near the top in almost any statistical table, whether it be a matter of bushels of corn, miles of railroad, number of people, gallons of whisky, or degree of intelligence. In amount of lumber production, however, there are more than thirty States

ahead of us, and it is our lot to be classed with such humble company as Maryland, Connecticut, and New Mexico. Forest planting might for us appear to be a much more fertile symposium topic. And indeed this *is* a topic about which much might be said. Although our State has a vast amount of land that naturally was treeless, there is scarcely a foot of this prairie area which is unsuited for the growth of trees. As a rule, it has been much more profitable to devote our marvellously rich soil to other uses, but there is reason for supposing that the time has arrived when we may well consider the desirability of tree planting to a much greater degree than has hitherto obtained. However attractive this subject might prove to be, it is not the one that has been assigned to me, and I must proceed forthwith to consider Forest Conservation.

Far from being one of the poorest states in which to exploit conservation theories concerning our forests, Illinois actually is one of the best, and for the obvious reason that it will not be necessary here to combat the undue cupidity of the lumber interests. In states like Washington or Louisiana, which are in the throes of extravagant timber exploitation, the sentiment of the ordinary intelligent citizens is against any large measure of forest conservation; as might be expected, the lumber interests in such states are vigorously opposed to any sort of conservation. Quite as unreasonable as the views of the average western lumberman, and very much harder for a rational conservationist to deal with, are the views of the idealistic conservationist, who lives for the most part well outside the regions of lumber exploitation, and chiefly in our cities. Many lumbermen are too much concerned in immediate gain to take thought for the future, and many conservationists are too impractical and too little familiar with forest conditions to be able to deal sanely with things as they are. One of the most pleasing signs of the times is the readiness of many of our most intelligent lumbermen to listen to plans of forest management which take the distant future into account; equally pleasing is the attempt made by the wiser conservationists to deal with the complex problem of forest conservation in the practical and conservative manner, which the name conservation ought to imply.

The establishment of forest reserves in our western states has met with vigorous opposition from many of the best citizens of the States concerned, and it is scarcely to be doubted that by the somewhat wholesale establishment of such reserves a good deal

of injustice has been done to legitimate present interests. It must not be forgotten that it is quite as wrong to reserve everything for our descendants, leaving ourselves in want, as it is to appropriate everything for present needs. Nor may one rely too much upon statistical presentations which show that after a certain number of years (usually startlingly few) our supply of timber will be exhausted. It is not so many years ago that our ancestors were worrying themselves into premature graves, because of the rapidly diminishing supply of whale oil. We well may laugh at our forefathers who paid high prices for the poor light that whale oil gave, while we revel in the numerous cheap and satisfactory methods of lighting which are given us by coal oil, gas, and electricity. And we may expect our descendants to laugh at us for many of the things which we worry about today. Who knows what inventions are to come that will enable us to do away with many of the economic uses of wood? Already the wooden house is being replaced, even outside the fire limits of our cities, by houses of brick, stone, or concrete; and one wonders just where, at the present rate of progress, the replacement of wood by concrete is going to stop. Steel also is replacing wood in the manufacture of railway cars, bridges, and in many other articles of construction. Possibly the somewhat exuberant zeal displayed by many of our lumbermen in forest destruction may be caused by the fear that the rapid replacement of wood by other substances is likely to leave them stranded with a lot of useless standing timber on their hands!

Whatever the merits of the discussion that is being carried on at long range between the lumbermen of the Far West and our city friends in the East, we well may congratulate ourselves that we in Illinois are not on the firing line. We can continue on in the even tenor of our way, and can indulge in a good deal of effective conservation without exciting a storm of controversy. This is not the only reason why Illinois is a peculiarly satisfactory State for the working out of conservation principles. Our forests are composed chiefly of the hardwoods, which as a class are much less subject to destructive fires than are the coniferous trees. Thus there is great likelihood that in Illinois long-continued experiments with timber tracts would not be suddenly terminated, as might be the case in a coniferous forest, no matter how carefully it might be guarded. Again, our Illinois forests are of unusual scientific interest because they abut upon the prairies. It is probable that, were artificial factors removed, the forest

area would gradually encroach upon the area of prairie. No problem has been or is more fascinating than this forest-prairie problem, and we are only just beginning to understand some of the factors involved, when we are faced with the danger of the destruction of all our natural areas of vegetation. This forest-prairie problem is not without its economic aspects, for it involves the natural forestation of treeless areas; if we can determine how and why natural forests develop on prairie soil, we will have discovered a principle of forestry of the widest significance.

The advantages of forests commonly cited by conservationists are as real in Illinois as elsewhere. These advantages are self-evident and may be mentioned merely by name. Erosion is greatly retarded by an effective forest cover; it would be possible to display views from various parts of Illinois, showing the destruction of rich layers of surface soil, owing to injudicious deforestation. Our prairies are often very windy, and wind incites excessive transpiration, which often is ruinous to crops; forests serve as effective windbreaks. Every farmer should have his wood-lot, and thus secure a large measure of independence; the wood-lot supplements the fuel supply and contributes much in manifold ways to the peace and prosperity of the farmer. The establishment of rational conservation and scientific forestry in Illinois will have an influence beyond the borders of our State. It is probable that those States which are now the chief seats of lumber exploitation will before many years realize the need of conservative forest management. Perhaps by then our State will have accomplished something of significance that may serve as a pattern for other commonwealths which were endowed more plentifully with natural forests of commercial importance.

Illinois has started well and in the right direction by acquiring land for a State reserve at Starved Rock, between La Salle and Ottawa, along the Illinois River. Doubtless this area would not now be a State preserve but for the remarkable combination of historic interest and scenic beauty, with features of botanical and geological importance, that are centered there. Several representative forest types are there displayed, and now that their preservation is assured they may be expected to increase in interest and beauty from year to year. At least four forest types are there preserved: the river-bottom type, with elms, hackberry, mulberry, box elder, willow, ash, coffee tree, honey locust, and many more; the ravine type, with the hard maple, basswood, and

ironwood; the rock-face type, with the white pine and arbor vitæ; and the upland forest, with the red oak, white oak, black oak, and hickory.

Much has been said concerning the preservation of the white pine forest in Ogle County, by all odds the most important forest of this species in Illinois. There is no question as to the desirability of preserving this forest, as a monument to future generations of the type of forest which was originally the most important forest asset of our country. It is believed that only a slight effort will now be needed to secure the purchase and preservation of this splendid forest. After this has been accomplished it would appear to be worth while to have set aside at least one example of each of the forest types of Illinois. Among these there should certainly be a river-bottom forest in southern Illinois, preserving some of the gigantic specimens of the primeval forest; a southern cypress swamp with its unique plant inhabitants; a yellow pine forest in southern Illinois; a beech forest; a tamarack swamp in northern Illinois. These are to be taken only as important samples; a number of other important forest types should also be included.

The forest reserves mentioned hitherto, probably should be State parks, but there remains to be mentioned a conservation scheme of yet wider significance. It has been proposed to establish county preserves; it is much to be hoped that this idea will be carried out. The expense involved should not be very great, and the return to the county would increase from year to year. In most counties such preserves might well be established in places of scenic interest, for such places usually have more or less diversified topography, displaying several types of forest and many tree species. These preserves would furnish places for picnics, and for excursions in connection with the nature study work of the schools; not only would the tree life increase in interest and beauty from year to year, but the same would be true of the wild flowers beneath the trees, and of the birds, and in fact of all kinds of plant and animal life. Bits of forest here and there would gradually be restored to the primitive wildness and beauty of the forests of pioneer days.

Possibly conservation might go even farther than has been generally suggested; that is, there might be township preserves, at least in many instances. In this event our forest tracts would be numerous enough to be within easy reach of all our people. All of our boys and girls could come into contact with forest life

in its many phases of beauty and interest, and all without any great expense and without any great sacrifice of arable land. With such development as this we might hope some day to approach the standard of efficiency illustrated by Germany, where, in a thickly settled and long civilized country, the forests are made to serve many interests, economic, scenic, educational. There the forest is an asset, as measured in financial terms, and it also ministers to German culture in various ways. What is possible in Germany is possible in Illinois, and more possible in Illinois than in most of our States, where forests are managed in terms of commercial exploitation rather than in terms of culture and human progress.

CONSERVATION OF OUR OIL AND COAL RESOURCES.

F. W. DeWolf.*

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INTRODUCTION.

The enormous increase in production of petroleum during recent decades has given rise to considerable study as to the

*The writer has drawn freely on reports of the U. S. Geological Survey, Van Hise's book on Conservation of Natural Resources, and Rice's paper on Mining Costs and Wastes: Bull. Ill. State Geol. Survey, No. 14.

total reserve in the earth, and the probable length of time before it will be exhausted. Petroleum serves so many unique functions in modern life that it seems indispensable; but in all probability its exhaustion is a matter of only a few years. It is said that if the present rate of increase in production continues, our known fields will be exhausted in twenty-three years; and even if the present production continues without increase the known supply will be gone within ninety years. These views are startling, but they are based on the best knowledge of the present time, with reference to the supply and demand at home and abroad.

PETROLEUM OUTPUT OF THE WORLD.

Since petroleum is an important element of the world's commerce, being easily transported by rail or water, the conservation problem at home is influenced by conditions in other producing countries. In 1910, thirteen countries produced a total amount exceeding 327 million barrels. The output in the United States equaled 64 per cent of the total; the Russian production equaled 21 per cent; and no other country produced as much as 4 per cent. Thus, the United States is by far the dominant producer in the world. The world's output in each year since 1906 has exceeded that of the previous year by 52, 21, 13, and 29 million barrels, or by an average of 29 million barrels.

PRODUCTION OF PETROLEUM IN THE UNITED STATES.

Output and Probable Duration.

Since the United States is by far the largest producer of petroleum, the conditions of production in our own country are the most important in connection with conservation. Since 1861, when the production was a little more than two million barrels, the output has doubled repeatedly within the following short yearly intervals: 9, 4, 7, 10, 12, 6.

The fields of the United States are shown in Plate I. The phenomenal increase in production is indicated by Plate II, which shows also the year in which new fields influenced the total production.

In order to know the effect of such increasing production on the duration of supply it is necessary to calculate the probable content of the oil sands in the known fields. The best estimates in 1907 indicated that the original supply was between 10 and 25 billion barrels. Calculation showed that the oil would be gone

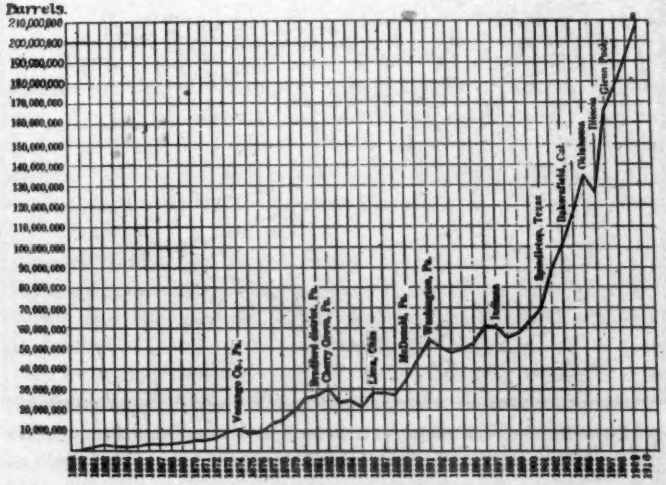
Plate I. Distribution of Petroleum and Natural Gas Fields in the United States. After Day, U. S. Geological Survey.

in 23 years if the production continued to increase at the same rate. It is interesting to notice that during the past three years the rate has been more than maintained, as shown by the illustration. Each field of the country reaches a maximum production and declines more or less rapidly. The Pennsylvania-New York field has declined in seventeen years to one-third of its maximum yield. West Virginia production has already declined to 56 per cent of its greatest output. Unless new fields are frequently discovered, an inevitable decline in total production is imminent.

Wastes of Petroleum.

In view of the irreparable loss of petroleum which follows its extraction, it is desirable to reduce as completely as possible the losses in production and utilization. The principal losses in extraction are indirectly caused by the fact that oil is mobile and that each owner in a given field is obliged to get his share as quickly as possible. Thus, facilities are not always provided for controlling the flow of new wells and of gushers. Frequently, no adequate storage tanks are provided and the oil lies for weeks in great earthen reservoirs, and is exposed to evaporation. These losses are indeed serious, but are subject to correction. A third

Plate II.



ANNUAL PRODUCTION OF PETROLEUM, 1859 TO 1910.

important loss comes from the fact that transportation for oil cannot always be provided promptly, and so the output is used for purposes which are extravagant. Thus, great quantities of oil which contain valuable distillation products are used under steam boilers and for oiling roads.

In view of the fact that oil is much more efficiently used in internal combustion engines, it should not be used for raising steam; and in view of our dependence on petroleum for lubricants and for isolated lighting, the continued misuse is deplorable.

MEANS OF CONSERVATION.

Ways in which our petroleum supply can be conserved have already been suggested. It is considered important to withdraw from entry those government lands which are probably underlain by oil, and thus to prevent over-production. The present exportation of 20 per cent of our oil annually should probably be reduced gradually. The recommendation is also made that research should be stimulated so as to provide more satisfactory combustion engines, and also to provide substitutes, such as cheap alcohol. There is some promise of successfully converting low-grade oils into better grades by means of chemical processes. Thus, and by similar intensive effort of producers, refiners, and the consuming public, it may be that we shall succeed in reducing ordinary losses, greatly extending the period of production and reserving petroleum for those purposes for which it seems to be indispensable.

CONSERVATION OF OUR COAL RESOURCES.

Our Interest in the Problem.

The whole world is vitally interested in conservation of coal resources. The total production for the year 1910 was approximately 1⅓ billion tons. Of this enormous amount the United States produced 500 million tons, or practically 39 per cent. The importance of Illinois mining is indicated by our production of approximately 10 per cent of the total for the country. Since America leads the world in production and apparently possesses the largest reserves, and since coal is mined here at a much lower

cost than abroad, it is probable that the world will demand exports from the United States at an increasing rate unless Federal laws prevent it. Although this demand will doubtless be met chiefly by the eastern States, Illinois coal in small part may sometime reach the Gulf by a deep waterway. It is evident, however, that we shall have more important and rapidly increasing demands for the States which comprise the heart of the country, and which are destined to support an enormous population engaged in manufacture and commerce.

Coal Fields of United States and of Illinois.

The coal fields of the country as shown by the accompanying map (Plate III), include 310,296 square miles and contained originally about three trillion tons of all grades. The Eastern Interior Region, of which Illinois comprises about three-fourths, included about 70 per cent of the coal of the interior States when mining began. The Illinois field includes 35,600 square miles, and is the largest area of bituminous coal known to exist in any State. The original coal in Illinois has been estimated at 200 to 240 billions of tons, though it will be many years before a close estimate can be made.

Growth of Coal Production and Mining Wastes.

Coal production in the United States is interesting because it affects the future in Illinois; and the inter-dependence of States unites us in the cause of conservation. Recorded commercial production began in the East in 1822 and amounted to 54,000 tons. The slow increase during early times and the enormous growth in recent years is pictured by Plate IV. This illustration is based on totals by decades, to the close of 1910.

Illinois production began about 1835, with a total of 6,000 tons for the year. In 1907 it exceeded 51 million tons, and since then has fluctuated between 48 and 51 million tons, chiefly because of labor troubles. The accompanying illustration (Plate V) shows totals by decades and resembles the previous diagram for the United States.

Total mining wastes have doubtless increased in manner similar to production; for it is estimated that for the country as a whole one-half ton of bituminous coal is wasted for each ton marketed. In Illinois it is probable that the waste is greater and approximates a full ton for each ton mined.

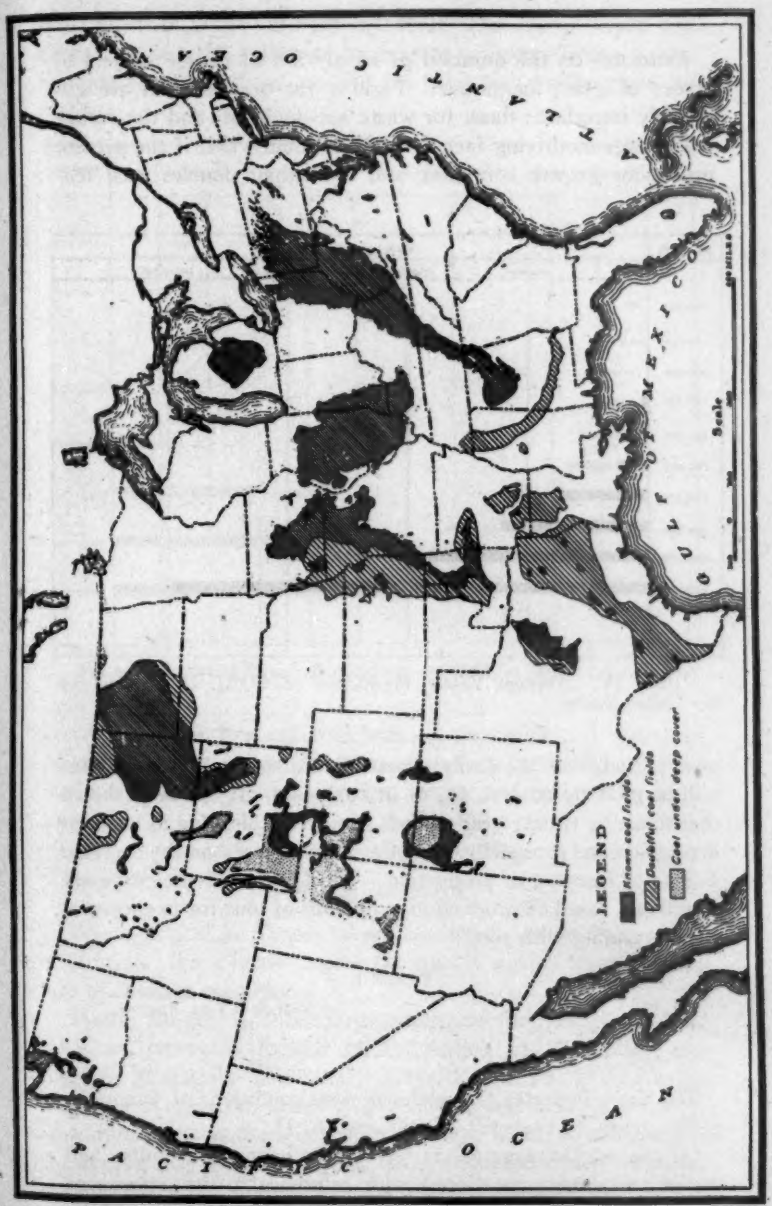


Plate III. Distribution of Coal Fields in the United States. After Campbell and Parker, U. S. Geological Survey.

Duration of Supply.

Estimates on the duration of supply are of course subject to errors of great magnitude. Figures for original coal are extremely uncertain; those for waste are doubtful; and the future holds large modifying factors. It is estimated that if the present marvelous growth continues, and the output doubles each ten-

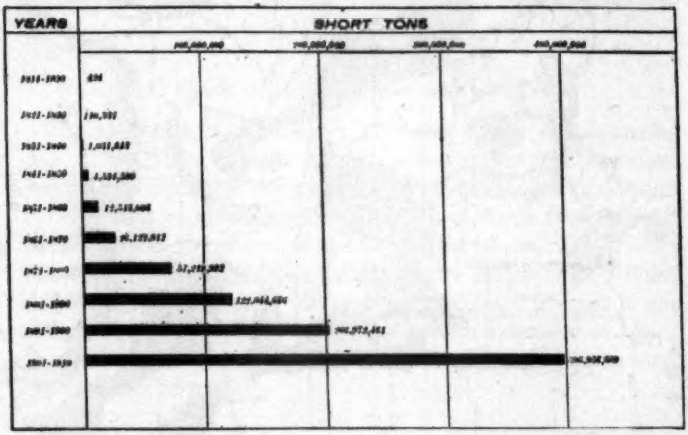


Plate IV. Average Yearly Production of COAL in decades for the United States.

year period, that the easily accessible coal of the United States will be gone by 2015 A. D., or in 103 years. It has been shown that totals by twenty-year periods avoid variables due to business depression and prosperity, and offer a curve based on the decrease in rate of increase of production. The figures for the curve are as follows, based on production in millions of tons for twenty-year periods ending with 1907:

TABLE I.

	Production, Millions of Tons.	Per cent of Increase.
1828-47	37.3	...
1848-67	306.0	720
1868-87	1451.0	374
1888-1907	5068.0	249

The curve indicates that under present conditions of waste our entire supply of coal will last till 2040 A. D.

Of course, the assumptions for such estimates are faulty; and the errors already mentioned with reference to the amount of

coal, together with doubt as to future demands at home and abroad, reduce the estimates to guesses. Nevertheless, in considering the lives of nations and the habitation of the globe, an

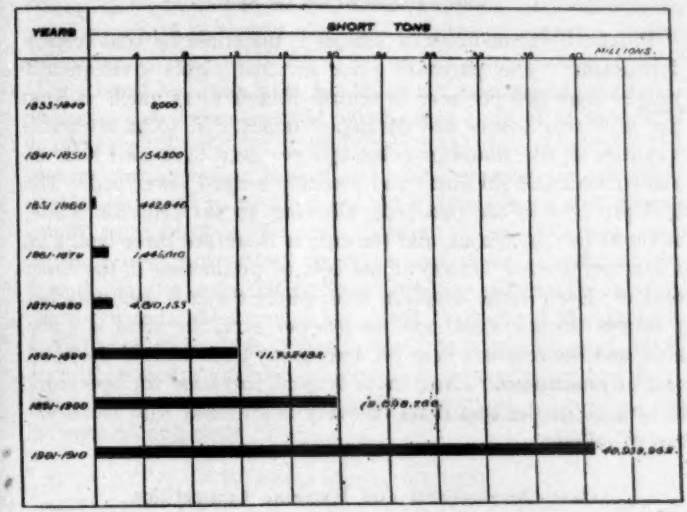


Plate V. Average Yearly Production of COAL in decades for Illinois.

error of one or two hundred years is negligible. It therefore behooves Illinois, as rapidly as possible, to take careful stock of our coal and to minimize wastes in mining and utilization.

WASTE OF COAL IN ILLINOIS.

General Statement.

Waste of coal in Illinois takes place chiefly in its mining and utilization. To a lesser degree the coal is wasted through non-use of cheaper substitutes.

Mining the coal is simple from the engineering viewpoint. The beds are unusually regular in distribution and thickness; and they lie practically horizontal. Nevertheless, the variations in recovery range from about 95 per cent to less than 50 per cent. Additional loss assumes importance locally, where subsidence due to mining may break overlying coals, and render easy recovery of the higher bed impossible. The chief reasons for the loss are

not engineering difficulties, but, rather, the cheapness of coal in the ground, and the low profits resulting from over-production and extreme competition.

Cost of Coal in the Ground.

Practically three-fifths of Illinois is underlain by coal-bearing formations. The purchase price of coal rights consequently ranges from $20 per acre in central Illinois to as much as $100 per acre near towns and developed mines. In some attractive localities in the southern fields $30 per acre buys two beds of known workable thickness and probably a third lower bed. The coal per acre in the two beds, allowing 50 per cent for waste, amounts to 10,000 tons, and the cost is therefore three-tenths of a cent per ton, or 1/1000 of the cost of production in the same region. Even in the northern field, where the coal measures but 3 feet in thickness and sells at $50 per acre, the yield is 5,000 tons, and the cost is 1 cent per ton, or 0.75 per cent of the total cost of production. Thus, there is small incentive for operators to save all of the coal if its recovery is attended with increased cost of mining.

Over-Development and Extreme Competition.

In 1909 there were 597 mines of commercial importance, which produced 50,529,370 tons. Practically the same mines in 1910 produced 46 million tons, with only 160 working days. It is customary for Illinois mines to meet the demand by operating only two-thirds of the year. The over-capacity of the mines is somewhat necessary because of the heavy demands of the cold winter months, but it leads to over-production and ruination of prices in months of lesser demand. It is then cheaper to operate without profit, or at a small loss, rather than to permit deterioration of plant and loss of important employees.

A great factor in prices has been the public demand for unnecessary variety in sizes of prepared coal. At given times, therefore, each mine finds itself obliged to sell uncalled-for sizes at an actual loss. Screenings, especially have been sold at a loss, but their increased use in automatic stokers promises improved prices. Large consumers have usually bought the sizes which are a drug on the market and small consumers necessarily pay the small profit which reaches the mine operator.

Illinois coal meets severe competition from other States as

well as from our own producers. The miners are better organized and secure higher wages in Illinois than in the principal competing States. In West Virginia, where the men are practically unorganized, coal was sold at the mine in 1910 at a price averaging 20 cents less per ton than in Illinois. This condition, together with low freight rates to Chicago and superior quality of the eastern coal, enables it to sell in our natural markets.

The latest available data for years not affected by wage disturbance, indicate an average selling price of $1.41 at the mines in northern Illinois and $0.88 to $1.15 in other districts. The average cost, including general and selling expense and amortization, averages $1.20 to $1.30 for the northern long-wall district and $0.70 to $0.95 in the other districts. The best gross profit probably does not exceed 20 cents, and when interest on the invested capital is deducted the net profit is reduced to 10 or 15 cents per ton; the average net profit throughout the State is probably much less than these figures. It is readily seen, therefore, that under present conditions it is nearly impossible to increase the percentage of mining extraction when this will increase mining costs.

Wasteful Mining Methods.

The above considerations show the controlling causes for the waste of about 50 per cent of our coal in mining. It is desirable next to consider the ways in which the coal is lost beyond recovery. They are due, in order of importance, to

1. System of mining.
2. Carelessness in operation.
3. Irregular boundaries of property.

Losses Due to System of Mining. Two general systems of mining prevail, as determined chiefly by the character of strata overlying the coal. The long-wall method of northern Illinois yields 90 to 95 per cent of the coal; but the room-and-pillar method, which is elsewhere in practice, commonly yields only 40 to 60 per cent.

Where the long-wall method is used, the coal averages 3 feet in thickness, and the roof is composed of shale, which settles gradually as the coal is removed. The miner undercuts the coal to a distance of 4 to 6 feet and the pressure of the roof breaks it down. Meanwhile props are set parallel to the face, so as to maintain a working place, along which fresh air circulates. Fallen shale and other refuse are continually piled behind the

miner, and the roof is taken down where necessary to maintain roadways. Under this system all of the coal can be recovered, but as a matter of fact shut-downs occasion some loss, because of falling roof and irregular alignment of the mining face. Remote corners of property may also be lost. However, recovery of 95 per cent is possible in spite of such losses. If the same method were applicable to all Illinois mines our conservation problem would be largely solved.

Unfortunately, the strata above the thicker coals of the State are so varied in character and strength that the room-and-pillar method is commonly necessary. Narrow passages are cut in the coal to serve for haulage and air circulation. Wider rooms are then mined out with the aid of coal pillars and room props to sustain the roof. It has been the common practice to abandon pillars when the rooms are finished.

One reason for leaving the pillars is that under prevailing systems, which prescribe narrow pillars and wide rooms, it is expensive, if not impossible, to recover the pillars. It may be pointed out that, if the mines were worked on a panel system with separate units surrounded by thick barrier pillars, and if rooms were narrow and room pillars thick, practically all of the coal could be recovered. It is encouraging to know that some of the large companies are now installing this system.

Another reason for leaving pillars is that surface subsidence frequently causes damage suits. The actual loss from surface subsidence should be negligible; for even with land values of $125 per acre, and with total loss of 80 per cent, or $100, the money loss would be only 1 per cent per ton of the coal in a 6-foot bed. As a matter of fact, the land would be as good as ever after full settlement takes place and deranged surface drains and tile systems are restored.

An important loss in some parts of the State where thick coal prevails comes from leaving 1 to 2½ feet of coal to form a roof. It is needed to strengthen weak shale during advance work. Although such coal can be recovered after rooms are worked out, it is not uncommonly wasted.

It is usually assumed that the room-and-pillar method yields 60 per cent of the coal, but it is probable than when unexpected losses, due to carelessness, are included, the average recovery for the State is not more than 50 per cent. A satisfactory remedy has been advocated for the present losses with room-and-pillar methods, but it is hard to introduce because it would increase the

preliminary period of mine development and defer profits three or four years longer than usual. The plan contemplates locating the shaft at the common corner of four sections of land, and cutting haulage ways to one side and thence to a corner. The coal could be completely recovered by retreating long-wall method, and the total cost of mining doubtless would be less than under present methods. The difficulty lies in the fact that two and one-half years would be required to drive the entries and make ready for profitable mining. The heavy cost during early years would rapidly decrease, and the closing years of mining would be more profitable, in contrast to the reverse conditions under present practice.

Losses Due to Carelessness in Operation. Besides wastes due to faulty system of mining, careless or inefficient operation is important. Failure to keep maps up-to-date frequently causes small blocks of coal to be passed by until too late for recovery. Surveys are not complete when mines are finally abandoned, and so future operators on adjoining properties are required to leave barriers of unnecessary size in order to be free from danger of gas and water in the abandoned workings. Again, pillars are left so small, or are "robbed" to such an extent, that roof and floor begin to "squeeze," and the coal is so crushed that large areas are abandoned. Fires, similarly, require the sealing off of large portions of the mines, and recovery is neglected. Another species of prevailing bad practice is the excessive use of explosives to blast down the coal. This causes an undue amount of fine coal, which either is not loaded out or is of low market value. In addition, this practice causes fatal explosions directly, or so weakens the roof that fatal accidents and the abandonment of parts of the mine follow indirectly.

Losses Due to Irregular Property Boundaries. A growing source of waste of coal is due to the purchase of land in checkerboard fashion, and to similar competitive tactics which isolate areas of coal, which are too small to warrant independent mining.

Waste of Coal by Improper and Unnecessary Utilization.

Generation of Power, Heat, and Light. Although it is difficult for one who is not a mechanical engineer to appreciate the wasteful utilization of coal, enough has been written on the subject to emphasize certain important features. Thus, the ordinary boiler utilizes only 5 per cent to 10 per cent of the fuel energy. Even

with mechanical stokers and best types of boilers only 15 per cent is used. Similarly, the ordinary steam engine utilizes only 5 per cent of the steam energy. The use of producer gas and gas engines has been shown to yield one brake horsepower hour with only 37 per cent of the fuel required under water-tube boilers. Large gas-engine installations have been made recently at Gary, Indiana, and the improvement is being slowly introduced into other large plants.

Another serious loss in the country is seen in coke ovens of the beehive type, which waste enormous quantities of volatile by-products. Modern retort ovens would save $50,000,000 annually.

Use of coal for domestic heating and lighting purposes is even more wasteful. Thus ordinary electric light utilizes only 1 per cent or less of the energy in coal. It is stated that 8 per cent, or 20,000,000 tons, of the coal used in making light, heat, and power goes up the chimney. Locomotives, of course, waste a much larger percentage.

It is obvious that the development of central plants for light, heat, and power is very desirable, for it will give smokeless combustion of low-grade coals, with the highest possible efficiency. Where possible, such stations should be located in the coal fields and the energy should be transmitted as electricity and coal gas. It is understood that long-distance transmission from the anthracite region to New York City is under consideration, and that the plan is also considered for Chicago.

Water Power and Solar Engines. The unnecessary use of coal where other forms of energy are available is, of course, deplorable. Attention has been called so emphatically to the enormous waste of water power that we may confidently look forward to the utilization of its full energy, to the limit of economical transmission.

The solar engine has been so far perfected, I understand, that an installation at Stanford University has operated economically in comparison with coal-fed boilers for a long period of testing. The apparatus comprises a large box covered with glass, and partitioned so that water circulates through it slowly, and is heated by the sun. All interior surfaces are black so as to assist absorption. The water becomes remarkably hot and is then vaporized slightly below atmospheric pressure for use in a steam turbine. The hot water is stored in buried reservoirs and operates the engine night or day.

It is not impossible that the use of solar engines of this simple

type will greatly reduce the consumption of coal in regions which are favored by plentiful sunshine.

Conclusions.

In view of the stupendous waste in mining and utilizing coal, it is evident that our utmost effort is needed to correct the conditions. Mining wastes can be checked by the adoption of long-wall system or by panel systems which provide for extraction of the pillars. Wastes in utilization can be cut down by the more rapid introduction of central plants equipped with the most efficient apparatus, and by the use of substitutes for coal.

It is evident that we need increased research by private concerns, and by State and Federal schools and bureaus, in order to display the clear facts in the problem and create closer relations between research and practice.

Coal operators for some time have advocated a law under which companies can combine and restrict ruinous competition. Some such means for increasing profit is doubtless necessary, to permit efficient mining and proper safeguards for life. Uniform interstate laws regarding extraction should be strongly urged in all producing States.

CONSERVATION IDEALS IN THE IMPROVEMENT OF PLANTS.[1]

DR. H. J. WEBBER,
New York State College of Agriculture, Cornell University.

The subject which I have chosen for my address may not appeal to you as having very close connection with topics ordinarily considered as related to the conservation movement, but it appeals to me as important. Whether I prove my case, I shall leave to you to judge.

The conservation movement had its inception in the wasteful methods practiced in the utilization of our national resources, such as our forests and mineral deposits. Alfred Russel Wallace, the great English evolutionist and contemporary of Darwin, has characterized the last century as a century of despoliation of the natural resources of the earth. Our forests have been ruthlessly

[1] Paper No. 30, Department of Plant-Breeding, Cornell University, Ithaca, N. Y.

destroyed until good lumber has reached a very high price and turpentine and resin in sufficient quantities to meet the world's requirements can scarcely be obtained. In the meantime large areas, denuded of forests, have been changed in climatic conditions and the fertile soils exposed to destructive erosion. Coal beds are being worked in ever increasing quantities and must ultimately be exhausted. The Chilean nitrate of soda deposits are approaching exhaustion. We use without thought of the morrow. The conservation movement has extended to the consideration of soil fertility, the proper utilization of water, of water power, of our land domain, and the like.

The problem of all problems confronting us is the necessity of increasing the production of food stuffs. How can this be done? Obviously the problem can be attacked from many sides, but the side which I desire to emphasize is the conservation of the best breeding stock of plants and animals. This seems a simple matter, but I am sure that the far-reaching possibilities of such conservation are not understood and are beyond our conception at the present time, as our viewpoint is necessarily limited by our present knowledge. Nevertheless the possibilities, as judged by our present knowledge, are so great as to place this factor, I believe, among the important features of the conservation movement.

What do we not owe to our domesticated and improved plants and animals? They are the greatest heritage which has come down to us from our ancestors. If the cultivated varieties and breeds of wheat, oats, corn, cotton, potatoes, cattle, sheep, hogs, and horses were all destroyed from the earth and we were forced to go back to wild nature, and begin the improvement over again, it is probable that the world would be almost depopulated and that the progeny of the few hardy individuals that survived would in the centuries that followed repeat the history of plant and animal improvement that has taken place in the past. Doubtless, however, new plants and animals now unknown to us would be the successful ones in the new evolution. That we now cultivate wheat, oats, corn, and the like, is probably in large measure due to attempts to artificially cultivate plants started in regions where the wild ancestors of these plants were native. In many cases the wild ancestors of our cultivated plants are not positively known.

It is not probable that the ancestral types have become extinct but that the cultivated forms have been so greatly modified that

the relationship cannot now be recognized with certainty. If *Ægilops ovata,* a wild grass of southern Europe, is the original ancestral form of wheat, as is supposed by some botanists, we have very many native grasses in various parts of the United States which, in an unimproved state, have much larger grains and would seem to be equally worthy of cultivation and improvement. If Teosinte (*Euclæna luxurians*) a wild, native grass of Mexico is the original wild ancestor of corn, as is believed by many scientists because of the fact that it is a native of the region where corn was first cultivated, is known to be subject to the same diseases, such as smut, and above all from the fact that it hybridizes readily with corn, we have an unpromising grass, so far as its grain its concerned, which has developed into our greatest of all grain crops.

Are we justified in assuming that all of the valuable plants and animals have already been introduced into cultivation? As a matter of fact, are we not justified in questioning whether the most valuable have been introduced? On sober second thought, does it not seem wonderful that wheat, a native of the Mediterranean region, should remain the best grain crop for a region including the greater part of British America and the United States, of Russia, and Argentina, and all the broad area where wheat is cultivated? Would it not seem probable that the improvement of the most promising native grain-grasses in these widely different regions would yield new types of grain crops better adapted to the regions and superior to wheat or oats? The great value of wheat and oats lies not in the superiority of the wild types from which they sprung but to the long years of cultivation and selection to which they have been subjected. A large number of wild grasses, occurring in almost every region. have comparatively large grains and if they were capable of improvement, as they doubtless are, they might possibly excel any grains which we now have. The Indian rice or water oat (*Zizania aquatica*) is an illustration of a large grained wild grass which is probably known to many. Doubtless this could be greatly improved for cultivation in low lands as rice is now cultivated.

The wild wheat grass (*Agropyrum occidentale*) of the great plains region is a very promising type for improvement, as pointed out by Dr. Bessey.[1] In this wild grass we have a head

[1] Bessey, C. E. Crop Improvement by Utilizing Wild Species. American Breeders' Association, Vol. II, p. 113.

five or six inches long and developing long, narrow grains much resembling wheat. It is a perennial and grows to a height of two or three feet. Dr. Bessey says of this plant: "If our plant had had but a fraction of the careful cultivation and selection which have been given the European species, I am confident that it would have yielded a much more productive cereal than we have in our present varieties of wheat." Consider, further, that we have here a perennial which would doubtless yield for several or, possibly, many years without reseeding, and also that it is a native of the great plains region and thus already adapted to the environment of the great wheat States of the Union. Of this grass and wheat, which would we expect to be best adapted to the "dry farming" regions of the West?

Several of the wild rye grasses (*Elymus*) have large heads and grains, and appear very promising, as do also certain species of the so-called beard-grass (*Andropogon*).

We have only considered the value of these grasses from the standpoint of their grain development, but it is of almost equal importance to consider their value as forage crops for animal food; and here much greater latitude of selection is possible. A very large number of our native plants should be tested, and the most promising improved for forage purposes.

In the development of leguminous crops we have a valuable field of research. Of the many hundreds of legumes, we now cultivate only about a dozen species, such as beans, peas, clover, alfalfa, crimson clover, cowpeas, soy beans, and the like, representing a natural adaptation to as many localities. None of the species ordinarily cultivated in the northern United States are natives of this great section. Yet an examination of the botanies shows that some one hundred and fifty different species of legumes are natives of this section. Would it not seem absurd to assume that our present cultivated species represent the best types for this section, when the most promising of those which the great Master Breeder gave us have not been thoroughly improved and tested? Among the wild native species of *Desmodium, Vicia, Lespedeza* and other legumes, we have a number of promising sorts. We have tested many of these species in comparison with our ordinary cultivated crops and discarded them, but our tests have been of the wild, unimproved against the improved types. We might as reasonably put gloves on a wild pygmy of Africa and test him on the mat with a trained modern athlete.

Doubtless the mere mentioning of the improvement of native plants suggests to the minds of each one of you some wild plant which you have observed and thought to possess valuable qualities. If our sources of nitrogen supply are to be exhausted soon, we must cultivate more leguminous crops which can gather their own nitrogen and improve the soil in this respect while furnishing crops. We should have leguminous tuber crops to take the place of potatoes, beets and turnips. Nature has given us such wild legumes as the ground nut (*Apios tuberosa*) and the Pomme de Prairie (*Psoralea esculenta*), which already have edible tubers, and which could doubtless be developed into very valuable cultivated plants by a few years of breeding.

Dr. J. Russell Smith,[1] of the University of Pennsylvania, has emphasized the importance of breeding tree crops, and here we have an inexhaustible field of experimentation. We should breed chestnuts, walnuts, hickories, oaks, beeches, hazelnuts, and the like, to improve them for the use of man and for growth as stock food. Many hundreds of thousands of acres of rough, hilly land, unadapted for cultivation, would be suited for the growth of such crops.

The possibilities of breeding tree crops are well illustrated by the excessive increase in vigor, rapidity of growth and size of fruit obtained by Burbank in a hybrid between the English walnut (*Juglans regia*) and the California black walnut (*J. californica*). "The hybrid," Burbank states, "grows twice as fast as the combined growth of both parents. The leaves are from two feet to a full yard in length. The wood is compact, with lustrous, silky grain, taking a beautiful polish, and as the annual layers of growth are an inch or more in thickness and the medullary rays prominent, the effect is unique." Another of Burbank's walnut hybrids, obtained by crossing the black walnut with pollen of the Californian black walnut, produces fruit of very much larger size than either parent. When we come to plant large areas to trees, as we are rapidly coming to do, imagine the immense value to the world if we could plant hybrids of rapid growth, such as Burbank's walnuts.

Who has tried to produce hybrids of maples, oaks, hickories, and pines, to get quick-growing hybrids for planting purposes? Who has hybridized such trees to get larger and better fruits? The world should not be compelled to wait much longer for

[1] Smith, J. Russell. The Breeding and Use of Tree Crops. American Breeders' Association, Vol. I, p. 86.

such improvements. We need the improved stock for planting. Some trees live a century before they reach young manhood.

Persimmons, pawpaws, huckleberries, elderberries, hawthorns, and hosts of other native fruits, are well worth improvement, and might be utilized not only for human food but for hogs, sheep and poultry.

Mr. Frank Rabak, of the Department of Agriculture, has recently shown that the black sage (*Ramona stachoides*), a wild California plant, and the swamp bay tree (*Persea pubescens*), of the southeastern United States, both contain a fairly high percentage of camphor and could be utilized for the manufacture of this valuable product. Doubtless these plants could, by breeding, be adapted to cultivation and the percentage of camphor increased.

The value of improving native plants has been strikingly demonstrated by the amelioration of our native grapes. The attempts of our early ancestors in America to grow European grapes uniformly met with failure, and finally, as a last resort, attempts were made to cultivate the native wild types. The marvelous success achieved, which has resulted in the production of a large number of fine varieties and established vine growing in the eastern and central United States, is one of the important achievements of our many-sided national history.

The same was true in the case of the gooseberry. The European varieties failing to succeed here because of the mildew, the small-fruited native species were introduced into cultivation, and the size of the fruits has been more than quadrupled in the improved sorts. Plums, raspberries, blackberries, and the like, furnish other illustrations of interest.

The native wild beggar weed (*Desmodium tortuosum*) has been introduced into cultivation in Florida, and without breeding improvement of any kind has in a few years won a permanent place in southern agriculture.

It may be argued that the improvement of our native plants would be too slow to justify attempts in this direction. I should answer that nothing is too slow which will pay. Nations bond themselves for hundreds of millions of dollars to carry on a war of the present, which bonds their children must pay some time in the future and for no compensation except to maintain the pledged honor of the nation. While breeding is slow when judged from the get-rich-quick standpoint of modern Chicago, it is not slow when compared with the life of a nation and from

the standpoint of permanent welfare. Within the memory of man the tomato has been introduced into cultivation and advanced in size from a fruit of three-quarters of an inch in diameter to our fine modern fruits, some of which grow as large as four inches in diameter.

A striking illustration of this nature is furnished by the experiments which the writer has conducted in the improvement of timothy. Timothy was introduced into cultivation about 1720, nearly two centuries ago. For many years it has been extensively grown, but no attempts have been made to develop improved races until recently. In experiments conducted by the Cornell Experiment Station, timothy seed was obtained from a large number of places in this and foreign countries, from which about 18,000 individual plants were grown, and the different types studied and isolated. As a result of nine years of work, some 200 different races have been secured, which show a very wide range of characters, and vary from dwarfs to giants in size. A test of the yields of seventeen of these new varieties, in comparison with the best timothy seed which could be purchased in the market, was made in 1910 and also in 1911. In 1910 the average yield of the seventeen new sorts was 7,451 pounds per acre, and that of the seven check plats of ordinary timothy was 6,600 pounds per acre, an average increase of 851 pounds per acre in favor of the new varieties. In 1911 the average yield of the seventeen new sorts was 7,153 pounds per acre, and that of the seven check plats was 4,091 pounds per acre, an average increase of 3,062 pounds per acre in favor of the new varieties. Four of the high yielding sorts in 1911 gave an increased yield of over two tons per acre, or practically double the average yield of the checks, which is an astonishing figure, and can be explained only by the fact that timothy has never been improved by breeding and still consists, as generally cultivated, of a motley array of many different types.

Hay is one of the largest agricultural crops of the United States, outranking all other crops, except corn, in total value of production. In 1910, according to the statement issued by the United States Department of Agriculture, there were grown in the United States 45,691,000 acres of hay, which yielded a crop having a farm valuation of $747,769,000. No statistics are available from which we can determine what proportion of this hay was timothy, but the writer believes that we may safely conclude that at least one-third of the entire hay crop of the country

is timothy. If this is true, the timothy crop of the United States in 1910 had a valuation of over $249,000,000. In the two years during which tests have been made, the seventeen new sorts gave an average increased yield of slightly over 36 3/5 per cent above ordinary timothy. A 36 3/5 per cent increase in the valuation of the timothy crop as above estimated would give us over $90,000,000 as the estimated annual gain in the value of the crop, which would be obtained if new sorts equally as good as these could be used throughout the country.

The rapid development of the science and art of breeding places us to-day in position to secure improvements much more rapidly than has been done in the past. It would not be astonishing if from twenty-five to fifty years of careful, intelligent breeding would accomplish with a wild plant what has required many centuries under the crude methods of our ancestors.

It may be asked why we should be in haste to take up the improvement of our native plants. In answer to this it may be stated that profound changes, such as we desire and must have, require time for their accomplishment. The potato and tomato did not reach their present perfection at one bound. A number of intermediate stages or improvements were first necessary. The strawberry and gooseberry did not reach their present size by one mutation, but several intermediate sizes were first necessary. Improvements apparently come by sudden leaps or mutations, and each of these paves the way for further development, which might never be possible without the first improvement.

In breeding, the time element is the limiting factor of importance. No permanent improvement of value can be obtained in a day, and no time should be lost in beginning on a scale commensurate with its importance the improvement of our native plants of promise. We must conserve time and fulfil our duty to succeeding generations. Why is it that such a small proportion of our lands are cultivated? According to the 1900 census, of the 1,900,000,000 acres of land in continental United States, only 838,000,000 acres were in farms, and of this area over 50.6 per cent was unimproved land. The sterile, sandy lands, and the low, wet lands, the stony lands, and the hill lands, the mountain lands of high altitude, and the barren lands of deserts, lacking water, and the like, all uncultivable and largely worthless for crops at present grown, make up far the larger part of our vast domain.

Travel through the high, hilly and mountainous regions of New

York, Pennsylvania, Maryland, Virginia, North and South Carolina and Georgia, and one finds vast areas covered mainly with a low growth of young trees and bushes, the main forests having been removed. The same is true of many extended areas in the central and western States. The utilization of these waste lands forms one of our great national problems, and the beginning of the solution of the problem rests in finding the crop best adapted to such areas, or in all probability in breeding crops that will be adapted to them. The necessity of using these waste lands in the near future is evident. Shall we plant them to forest? Certainly much of this land should be in forest, or in tree crops of some sort, but we want tree crops, at least in many cases, that will return food as well as shelter. The Italian yield of chestnuts is said to average twelve bushels per acre, and J. Russell Smith states that "the value of European mountain-side chestnut orchards equals, acre for acre, the Illinois corn belt." The kinds of trees to plant in such areas for wood, for fruit, for sugar, starch, camphor, or forage requires careful study and the proper breeding to secure the best sorts possible.

But this is not all of the problem. Grain, forage and special fruit crops, not necessarily forest trees, require to be as carefully considered, and here again breeding to secure good species adapted to the conditions will be the keynote of success. All this requires time, and the generations to follow will not have the time, and certainly not the money, if they do not repudiate our war debts. The work should be started immediately in order to obtain the results when conditions demand them. When I urge this as one of the important national problems of conservation, I speak not without some authority. My life has been given to agricultural work in various parts of the United States. My boyhood on an Iowa farm gave me a knowledge of the rich prairie regions of the West. My education in the universities of Nebraska and Missouri extended that knowledge. My sixteen years of service in the National Department of Agriculture, working with cotton and oranges in Florida, Georgia, Alabama, Mississippi and Texas, taught me southern conditions and demands, and now my experience of the last five years in Cornell, associated with that Master Agriculturist, Dean L. H. Bailey, has broadened my horizon to at least some conception of the field of agricultural education.

As to the possibilities of producing the suggested improvements in plants, it again may be granted that I can speak with

some degree of authority, in view of the fact that the great cotton, corn, timothy, orange and pineapple industries have, at least in certain places, felt the influence of new varieties that have gone out from my laboratory. I say this not to extol myself, as any man in my place with my opportunity could have accomplished the same results, and many would have done very much more. I say it simply to lend weight to my statements before you who are strangers.

I can by no words of mine present this problem in its importance as I see it. In no way, probably, can my efforts stir the nation to a recognition of the necessities of this case, so that action will not be too long delayed. Recognizing the urgency of the problem as I do, however, I would be remiss of my duty did I not use such powers and gifts as have been given me to urge forward a project which sooner or later will be recognized as one of the keystones of the conservation movement.

The materials for the consummation of the ideals I have presented are all around us. The brawn and brain for the service are awaiting the opportunity. The service will be long and difficult, however, and the servant must live while engaged in the task. Only by long consecutive years of service can the highest ideals be reached. Men must consecrate their lives to this achievement. The service will be pleasant, and the scientific results gathered from year to year will repay the worker; but means must be found to place the investigator beyond the temptation of other employment, as permanency of tenure in such work will be of the highest importance. It is a work for the State and the Nation, but I fear they will be too slow to recognize the long-time requirements of the work. Political institutions demand too quick results. I feel that the most hopeful method of accomplishing some of the ideals outlined is through endowed institutions. To what more serviceable task could benefactions be devoted than to the solution of such problems, and what type of institution would return more credit to the donor? Institutions to conduct such work could be tied up with some of our great universities to establish the proper scientific relationship, and should be in such close coöperation with these universities that graduate students could be utilized in connection with the investigations and trained in the service.

In summarizing this discussion I may say that to one unfamiliar with the possibilities of breeding, the outcome of such experiments may appear doubtful. We need no lamp to guide us,

except that of experience. When we realize the little promise exhibited by the native grapes, tomatoes and potatoes, from which our cultivated sorts have sprung, we gain a conception of the tremendous increases which can be brought about by a century of cultivation, even when the breeding is of desultory nature. Couple with a century of time—aye, fifty years—the skill of trained breeders, and what might we not accomplish? The greatness of the possibilities stretches before the enthusiastic breeder as his mind spans the years filled with the battles of conquest and achievement in the building up of new industries, like a panorama of the wars and struggles in the building of a nation. Man's creative genius is touched. It appeals to him in its vastness as a challenge. The trained man in the field of breeding feels the certainty of his power. He longs for the conquest.

Geological Papers

THE STRUCTURAL RELATIONS OF THE OIL FIELDS OF CRAWFORD AND LAWRENCE COUNTIES, ILLINOIS.[1]

RAYMOND S. BLATCHLEY.

The State Geological Survey began a detailed investigation of the geological conditions in the southern half of the eastern Illinois oil fields in 1908. This work was carried on intermittently and was finally completed January 1, 1912. The specific area of investigation lies in the southern half of Crawford and the central portion of Lawrence counties. The primary object of the work was to determine the cause of the accumulation of oil and gas and to secure facts which would have a bearing on the origin of oil, and also to determine, if possible, the relation of the quantities of oil, gas, salt water, porosity of the sand, etc., to the structural features of the sand.

The work is based upon the elevations and records of 5,200 wells. The method of study is to map, by means of contour lines, or lines through points of equal altitude, the geologic structure of the producing sands. The contours are made upon the positive altitudes of the sands above a datum plane 1,500 feet below mean sea level. These maps show the oil sands as if everything above them had been removed. From the undulations on the surface of the sands and from the initial productions of the wells, the oil, gas and water relations to the structure are observed. The La Salle anticline is the controlling feature of the field.

CRAWFORD COUNTY.

The investigated area in Crawford county lies south of the Illinois Central Railroad, between Oblong and Robinson. There are 2,970 wells mapped in this area, of which 206, or 8.7 per cent, are barren. The productive wells range in initial yield from 1 to 1,600 barrels. The Robinson pool, or that of Crawford county, is about seven miles wide between Robinson and Oblong, but narrows to about three and one-half miles at the southern limit of the county. The western boundary of the field trends northwest and southeast and is sharply defined. The eastern boundary, on the other hand, is very irregular.

[1] This paper with illustrations was published by permission from the Secretary, in Economic Geology, Vol. VII, p. 574, 1912. Also a more complete report with abundant illustrations will appear as Bulletin 22, Illinois State Geological Survey.

All the penetrated rocks in the producing areas of Crawford county belong to the Pennsylvanian series. This series is represented by about 480 feet of the McLeansboro, 300 feet of the Carbondale, and about 100 feet of the Pottsville formations. The rocks are all of sedimentary origin, being principally shales with variable intergradations of sandstones, limestones and coal. The oil sands lie at the top of the Pottsville rocks, which are the lowest members of the Pennsylvanian, and are essentially coarse sandstones, merging into sandy shales at the top, and often split with lenses of shale and pockets of coal.

The Crawford county pools have one general oil-producing zone, known as the Robinson sand, lying between 800 and 975 feet deep. This sand is so broken and lenticular that it offers little opportunity for structural study. In some portions of the field it assumes regularity in its distribution. It is split into two or three persistent lenses that show an average interval of about fifty feet and a thickness of from two to fifty feet. The lenses often merge into each other and are even united in some wells with a maximum thickness of 122 feet. Again, the lenses pinch out, and in several wells are entirely absent.

Owing to the irregular deposition of sands and shales, it is impossible to correlate and contour any sand beds definitely, except the top lens of the Robinson sand. Even this work loses much of its scientific value in places where the sand wedges out or is overlapped.

The altitudes of the top lens are assembled and contoured with intervals of twenty feet. The general structure of the Robinson pool reveals a broad and gentle arch, which is divided into two parts by a transverse basin. The north part of the arch is six miles wide, with its crest ninety-five feet above the lowest explored portions of the limbs. The south part of the arch is about four miles wide and 110 feet high. The 1,100-foot contour follows the limits of the pool in a general way and seems to include most of the productive zone. The small irregularities of the map probably do not represent minor folds, but irregular porosity of the general sand zone, as determined by the driller.

In studying the distribution of oil over Crawford county, the lower lenses are found slightly more productive than the top lens. There is considerable unevenness of distribution due to the following factors:

1. The sands vary in porosity and in many places are practically impervious to oil.

2. The sands thin and thicken rapidly, and in some localities pinch out altogether.

3. The sands are so irregularly interbedded with the shales along the productive zone in some areas as to prohibit extensive collection of oil, gas and water.

4. The best productive areas have twenty to forty feet of sand and are usually free from large amounts of salt water.

5. Local dry spots in the midst of very productive territory cannot be attributed to small depressions or knolls in the sand bodies, but rather to the non-porosity of the bed.

Salt water does not uniformly fill the rocks of the region, although there are many dry strata which are porous. Great quantities of salt water occur upon the limbs of the anticline beyond the productive area and in the Illinois basin to the west. All the lenses of the Robinson sand are well saturated along the definite boundary line on the western side of the pool. The upper lenses are generally barren of water within the pool, while the lower lenses reveal water across the fold and, in some localities, under the oil. Since the oil lies near the top of the lower sand lens, but few wells pass through the oil stratum into the water, for fear of drowning out the oil.

It is obvious from the position of the water and oil along the La Salle anticline that the water has controlled the accumulation of oil in the arch. The water probably has originally permitted the oil to migrate long distances up the slope of the Illinois basin into the arch. This was effective for all lenses of the Robinson sand, although the degree of saturation is variable over the crest of the arch.

LAWRENCE COUNTY.

The oil field of Lawrence county offered the best opportunity for geological study because of the depth and number of oil horizons and the abundance of records. The field is seventeen miles long and three miles wide. There were 2,180 wells studied, of which 156 or 5½ per cent were dry. The range of initial production lies between 1 and 2,400 barrels. The field trends northwest and southeast, with the northern limit on the Crawford-Lawrence county line. The field changes its course about twenty degrees near Bridgeport. The western edge of the field is well defined like that of Crawford county, and similarly. The eastern edge is irregular. The Lawrence county field is the richest in

Illinois, and has produced more large wells with steadier yield than the rest of the fields combined.

The explored rocks of Lawrence county lie in the Pennsylvanian and Mississippian series. The former are from 800 to 1,300 feet thick; the latter are, as a rule, penetrated only to a depth of about 475 feet.

The Pennsylvanian rocks of Lawrence county include a shallow producing sand at the south end of the field, probably in the McLeansboro formations; the Bridgeport sand, of three lenses, in the upper part of the Pottsville formations, and corresponding to the Robinson sand of Crawford county; and the Buchanan sand in the basal portion of the Pottsville rocks.

The Mississippian rocks underlie the Pennsylvanian and contain the most important oil sands. The upper part is known as the Birdsville and Tribune (Chester), followed by the Ste. Genevieve and the St. Louis limestones. The Chester beds include the so-called "Gas," Kirkwood and Tracey sands, while the Ste. Genevieve contains the rich McClosky sand. The sand names are those of land-owners upon whose farm the sand was first tapped. The Chester rocks average 365 feet in thickness, in comparison with 700 feet in southwestern Illinois.

The "Gas" sand, or first sand in the Chester, produces gas locally over Petty township of Lawrence county. It is 125 feet beneath the top limestone of the Chester and 198 feet lower than the Buchanan sand of the overlying Pottsville.

The Kirkwood sand is the most widespread producing horizon in Illinois, as well as in Lawrence county. It is correlated with the Sparta sand of Randolph county, the Carlyle sand of Clinton county, the Lindley sand of Bond county, the Benoist sand of Sandoval in Marion county, all of Illinois, and the Oakland City sand of Pike county, Indiana. The Kirkwood sand shows excellent initial production and long continued yield. It is the most reliable of all the sands. The oil is "sweet," or with small percentage of sulphur. The top of the Kirkwood sand is 192 feet beneath the top of the Chester, sixty-seven feet below the top of the "Gas" sand, and usually lies about in the middle of the Chester rocks.

The Tracey sand is stratigraphically equivalent to the Cypress sandstone, and is usually about 317 feet lower than the top of the Chester and 114 feet beneath the Kirkwood sand. This sand yields gas under high pressures and some oil. The gas has a rank odor and the oil from this sand is "sour," both due to the

large sulphur content. The Tracey sand is so closely associated with the underlying limestones that its oil and gas probably had their origin from the included marine animal life of the limestones.

The Ste. Genevieve limestone has a total thickness of eighty-five feet and contains the McClosky sand, which has proven the most prolific oil horizon in Illinois, because of exceptional initial flow and steady yield. This pool has been instrumental in upholding the Illinois production when other sections were declining. The range of depth for the sand is 1,550 to 1,850 feet, or about 446 feet lower than the top of the Chester and 104 feet beneath the top of the Tracey sand. The oil is found twenty to fifty feet in the limestone.

The detailed structure of the Lawrence county oil field is shown by five contour maps of oil sands and four cross-sections of the field. The structure map of the top of the Kirkwood sand is representative of the lay of the rocks in the area. The altitudes of this sand are assembled and contoured with twenty-foot interval. The most conspicuous feature revealed is a double plunging anticline or elongated dome lying in section 30, Petty township, which is 400 feet high and 3 miles wide. The crest of this dome lies within the 680-foot contour. The sand dips from the crest of the dome northward at the rate of forty-one feet per mile; southward, sixty-three feet per mile; eastward, 194 feet per mile; and westward, 228 feet per mile. The sand dips southward from the dome into a small syncline in the southwest corner of Lawrence township and then spreads fanlike in its structure to the southeast through Lawrence and Dennison townships on to a broad plateau-like crest of the major fold. In this locality the sand lies at the 400-foot contour level. The southern limits of the field seem to gradually dip lower than the producing zone of the sand. Whether the major fold continues to dip and merge into the southeastern side of the Eastern Interior Coal basin, or the dip is local, as seems to be the case between Crawford and Lawrence counties, is not known.

The other structure maps of the Buchanan, "Gas," Tracey and McClosky sands corroborate and conform to the structure of the Kirkwood sand, with the exception of very minor irregularities. In addition to these maps, four cross-sections were made to show the nature of the crest of the La Salle anticline, as well as its flanks. The A-A cross-section presents the structure of the sands along the crest of the anticline and lengthwise through the oil field. The section is valuable for its picture of the double

plunging anticline, the convergence of the sands at the northern end and the mergence of the dome into the flat at the southern end of the field. The sands are generally parallel with local irregularities that seem due in most cases to the thinning and thickening of the sand. The remaining sections are plotted crosswise to the fold and reveal the amplitude of the arch.

The largest amounts of oil in the Lawrence county field are in the extensive flat area in the southern half of the field, and at a level of about sixty feet below the crest of the dome in the northern division.

The sands of Lawrence county show abundant water along the lower flanks of the anticline and but little through the center of the field, except in the lower Bridgeport and Buchanan sands. These Pottsville rocks appear well saturated with water over the entire field and into the limbs of the La Salle fold. The underlying Chester sands are not uniformly saturated with water, but seem to have lines of saturation along the limbs of the fold, more particularly along the western side.

SUMMARY.

The features of the structure maps and their individual oil, gas and salt water relations, just described, are sufficiently similar to permit general conclusions regarding the accumulations of oil and gas in Crawford and Lawrence counties. These conclusions add to the general fund of evidence relating to the accumulation of oil and gas in raised rocks.

The greater part of Illinois lies within the Eastern Interior coal basin, which is, broadly speaking, an extensive spoon-shaped basin, with its axis extending along a line, through Cerro Gordo, Lovington and Olney and into its deepest part in Wayne, Hamilton and Edwards counties. The east side of the basin rises into a strong longitudinal fold known as the La Salle anticline. The ascent is at the average rate of about fifty feet per mile, but it is more rapid in Lawrence county, as shown by contours of the very sharp apex of the anticlinal dome. The basin and lower flanks of the fold are known to yield abundant water in all the sands which are productive in the main fields. The uppermost part of the flanks of the major fold contain abundant oil. The western limits of the fields are abrupt, and beyond this line the sands are wholly water-bearing. Enough data are at hand to conclude that this is a line of water saturation and that above this line and over the fold most of the sands are oil-bearing.

The accumulation of oil and gas in their present position may be looked upon as ideal, and is presumably due to the following factors:

1. There is an extensive anticline with a marked basin on at least one side.
2. The depressions on both sides of the fold, showing abundant water, comprise extensive "feeding" areas for the arch.
3. The sands are commonly porous, and hence form suitable reservoirs.
4. There are abundant shales and some limestones overlying the sandstones, which probably serve as impervious covers to the reservoirs.
5. The sands in both limbs of the anticline are abundantly saturated with salt water, which is probably instrumental in holding the oil and gas captive in its present position.
6. Although the general structure of the oil fields is dominated by a major fold, its crest is very irregular and is interrupted by numerous minor domes and transverse depressions, which, together with irregularities in porosity, have been instrumental in segregating the pools.
7. With one exception, the best collection of oil was found over the broad flat areas. The domes over the entire field are logical gas reservoirs, but, contrary to expectation, the largest amounts of gas and oil do not lie at the apexes of the domes, but a short distance below.

GEOLOGICAL SEQUENCE IN THE VICINITY OF LA SALLE AS REVEALED BY RECENT DRILLING.

GILBERT H. CADY.

Within the last two months the State Geological Survey has received the drilling samples from two new wells in the vicinity of La Salle that penetrate strata to the depth of from 1,200 to 1,500 feet. The presentation of the records or logs resulting from the study of these two sets of samples, and their interpretation, is the first purpose of this discussion. There were also available for comparison the records of several wells in the vicinity of La Salle, some quite recently drilled, and others dating back before 1890. Of some of the latter, the drilling samples have been studied by Dr. J. A. Udden, and the results of his

study appear either in the detailed cross-section of northern Illinois prepared for the Report of the Illinois Board of World's Fair Commissioners or in his correspondence with the Director of the State Geological Survey. Following the interpretation of the new logs, a comparative study of the records of a number of the wells in the vicinity will be undertaken. In conclusion, as a summary of the data presented, and in order that a broad application to conditions in the State may be made, a revision of the Udden cross-section from Rock Island to the east side of the State will be presented and discussed.

PRESENTATION AND INTERPRETATION OF LOGS.

In way of preparation for the discussion and interpretation of the two new logs, a general understanding of the geological sequence in northern Illinois and of the structure in the vicinity of La Salle is necessary.

The northern Illinois section, summarized by R. S. Blatchley in his paper on Illinois Oil Resources in Bulletin No. 16, State Geological Survey, page 60, is in brief as follows:

		Feet.
Coal measures		575
Devonian		
	Sweetland Creek shale	40
	Iowan Hamilton limestone	150
Silurian.	Niagara dolomite	335-388
Ordovician		
	Maquoketa shale	68-250
	Galena-Trenton	300-440
	St. Peter sandstone	150-275
	Lower Magnesian limestone	450-811

Unconformities exist between all the divisions, except between the St. Peter sandstone and Trenton limestone, and possibly even locally there.

On page 28 of the same volume, G. H. Cox describes the rocks of the Lower Magnesian formation and separates it into the following members:

	Feet.
Shakopee dolomite	40
New Richmond sandstone	15-130
Oneota dolomite	200-225

The Lower Magnesian rests on the Potsdam formation of the Cambrian.

The Pennsylvanian of northern Illinois is separated into three members: the McLeansboro, Carbondale and Pottsville forma-

tions. The Pottsville lies below No. 2 coal. It is characterized by silicious, micaceous, gray or reddish shales, and sandstones which are often micaceous. Occasionally there occurs a thin bed of coal in the formation. In the main it is non-calcareous. The texture and color, together with the lack of calcareous material, are important criteria of discrimination.

The Sweetland Creek shale, a dark colored shale, at least its lowest part, is often colored brownish by an abundance of fossils known as *Sporangites huronense,* supposed to be the spores of some paleozoic tree. These are readily distinguishable, and render the correlation of a shale containing them very accurate. The Hamilton limestone is a light gray, pure calcareous limestone, not a dolomite. Considerable hesitancy should be shown in correlating any dolomite with the Hamilton.

The Niagara limestone is generally a dolomite of very fine texture, usually of a light color, and sometimes characterized by layers of flint. In certain places the Niagara limestone is known to contain calcareous layers.

The Maquoketa shale is very variable in lithological character, but bluish-gray shale with some streaks or beds of limestone and black carbonaceous shale is the usual occurrence. The relationship of the overlying and underlying formations are the readiest means of identification.

The Galena-Trenton formations are dolomite in the upper part, the lower sixty or 100 feet of Trenton, however, being usually more calcareous. The upper part is usually of a characteristic brownish-buff color, due to a large percentage of iron present. The Trenton is often bluish. Both formations are often quite flinty; this is especially true of the Galena and the lower or quarry beds of the Trenton.

The St. Peter sandstone is characteristically a pure, soft white sandstone, the individual grains being all quartz and of a rather large size. Its purity, color and softness are almost unfailing criteria for identification.

The Lower Magnesian limestone, or Shakopee dolomite, is a white flinty dolomite, often having beds of fine laminated hydraulic limestone. It sometimes contains silicious concretions. The upper part in contact with St. Peter sandstone is usually marked by the occurrence of oölitic flint. The beds lower than the Shakopee dolomite are nowhere exposed in Illinois, and their local characteristics are not known.

The structural feature to be emphasized in the northern part

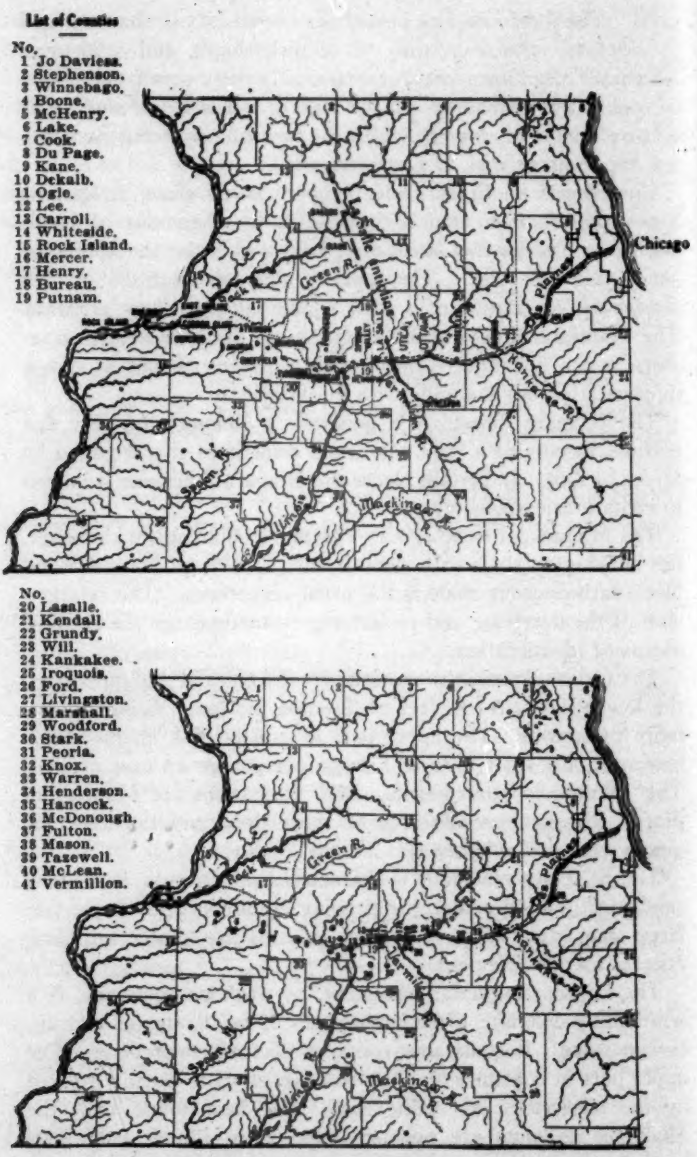


Plate I. Maps of Northern Illinois showing locations of towns and drill holes between Rock Island and Joliet.

of the State relative to the region of our investigation is the La Salle anticline. Its position is indicated on the map. (Plate I.) Its character has been discussed so frequently that it has become familiar. The fold is more in the nature of a monocline than an anticline, the west side being thrown down along the axis of disturbance and the east side thrown up. The details of the structure at La Salle will be shown by the cross-section.

The two new logs to be presented are from wells located in the lowest part of the trough west of the anticline.

Log of well No. 16, at the Western Clock Works in Peru, is as follows, continuing from the base of coal No. 2, or the third-vein coal, as it is locally known. This log is diagrammatically shown on the chart.

Fireclay	5 feet
Sandstone	30 "
Gray shale, dark, indications of coal	70, base 500 feet deep
White calcareous sandstone	15 feet
Hard red shale	3 "
Gray and green shale	30 "
Hard red shale	3 "
Green and gray shale	85-90 ft., bottom 650 ft.
White dolomite	36 feet
Brown	8 "
Light gray dolomite	96 "
Buff dolomite	15 "
Light gray dolomite	23 "
Buff dolomite	12 "
Light gray dolomite	13 feet, bottom 853 feet
Bluish gray dolomite	70 feet
Brown shale	10 "
Gray shale	100 feet, bottom 1035
Brown dolomite	85 feet, bottom 1120

Log of well No. 27, at No. 5 mine of La Salle County Carbon Coal Co. Coal No. 2, or third-vein coal, at elevation of 135 A. T. depth 565 feet:

Gray shale	125 feet
Fine sandstone	40 "
Gray shale	35 "
Sandstone	10 "
Light gray shale	25 "
Gray and green shale	25 feet, bottom 825 ft.
White dolomite	75 feet
Brownish dolomite	25 "
Light gray dolomite	25 "
White dolomite	50 "
White, slightly calcareous dolomite	25 "
White, chalky calcareous dolomite	25 "
Buff dolomite	23 "
Gray dolomite	20 "
Shale	5 "
Blue and brown shale	145 "
Brown dolomite	255 feet, bottom 1498 ft.

the last 15 ft. somewhat calcareous.

It is apparent that the strata can be divided into four parts, lithogically. There is an upper division composed of shales and sandstones and possibly a little coal; the second division, consisting of lighter colored dolomites; the fourth, made up of light gray and bluish shales, with a little dark shale, and finally the brownish dolomite.

A detailed comparison of the first limestone of the two logs shows a little similarity throughout; both have a succession somewhat as follows: White dolomite at top, followed by brown dolomite, gray-white dolomite, then a thin buff dolomite, with the bottom a gray dolomite, so that there seems to be great safety in the correlation of these two limestones.

Having established the correlation of the upper limestone, the lower strata fall into order. Checking the lithogical characteristics of the four divisions of this well with the character of strata outcropping in northern Illinois, previously described in this paper, it would appear that the upper limestone is probably Niagara limestone and that the Maquoketa shale and Galena-Trenton limestone lie below. The Hamilton limestone does not occur in these logs. The material composing the shale of the first group might be Devonian or Pottsville, but the absence of bituminous beds with Sporangites seems good proof that the upper Devonian or Sweetland Creek shale is here absent and that the strata all belong to the Pottsville.

To summarize: We have below No. 2 or third-vein coal 250 feet of Pottsville sediments, 200-250 feet of Niagara sediments, 145-180 feet of Maquoketa sediments, and as much as 300 feet of Galena-Trenton, neither well having certainly penetrated the horizon.

COMPARATIVE STUDY WITH OTHER RECORDS.

In the comparative study of the records just summarized with the records of other wells in this locality, wells Nos. 16, 31, 15, 14 and 13 will be included in the discussion. (See Plate II.)

These wells are for the most part located in a linear manner along the north bluff of the Illinois River, extending from La Salle to Bureau (See Plate I), and they will be considered in order from east to west.

Well No. 30, Illinois Zinc Co., about one-quarter mile west of well No. 16:

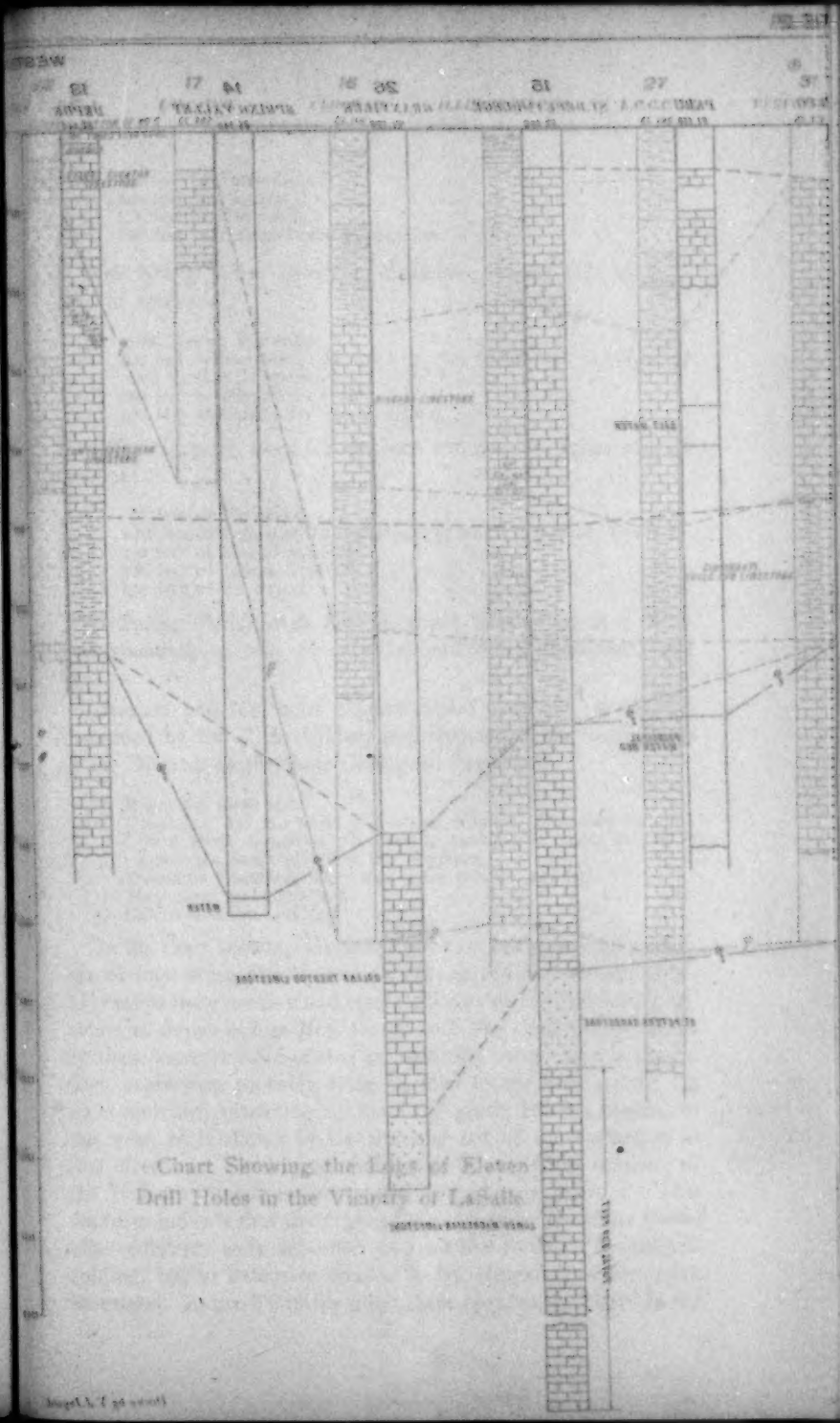
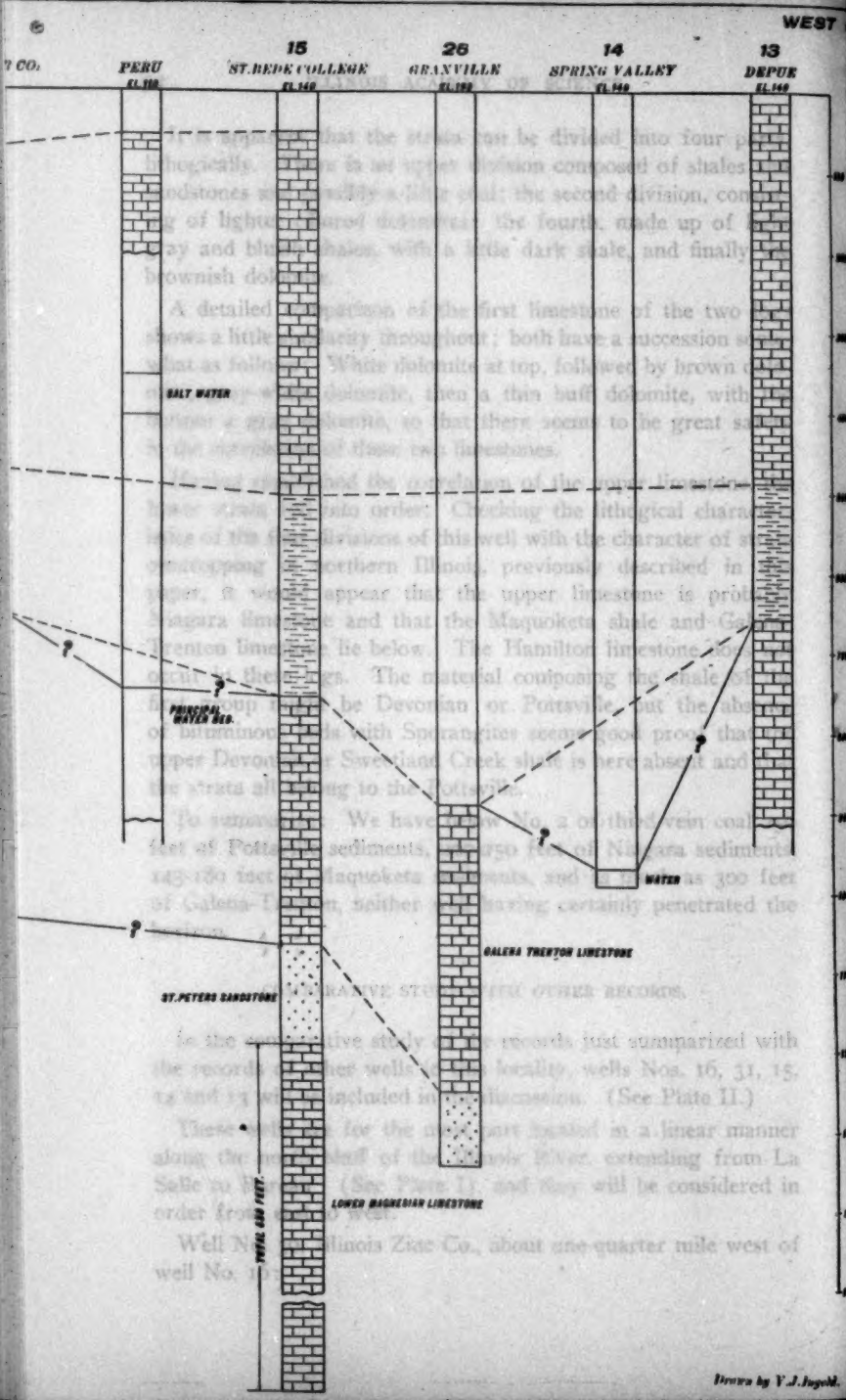


Chart Showing the Logs of Eleven
Drill Holes in the Vicinity of LaSalle



Drawn by V. J. Jugold.

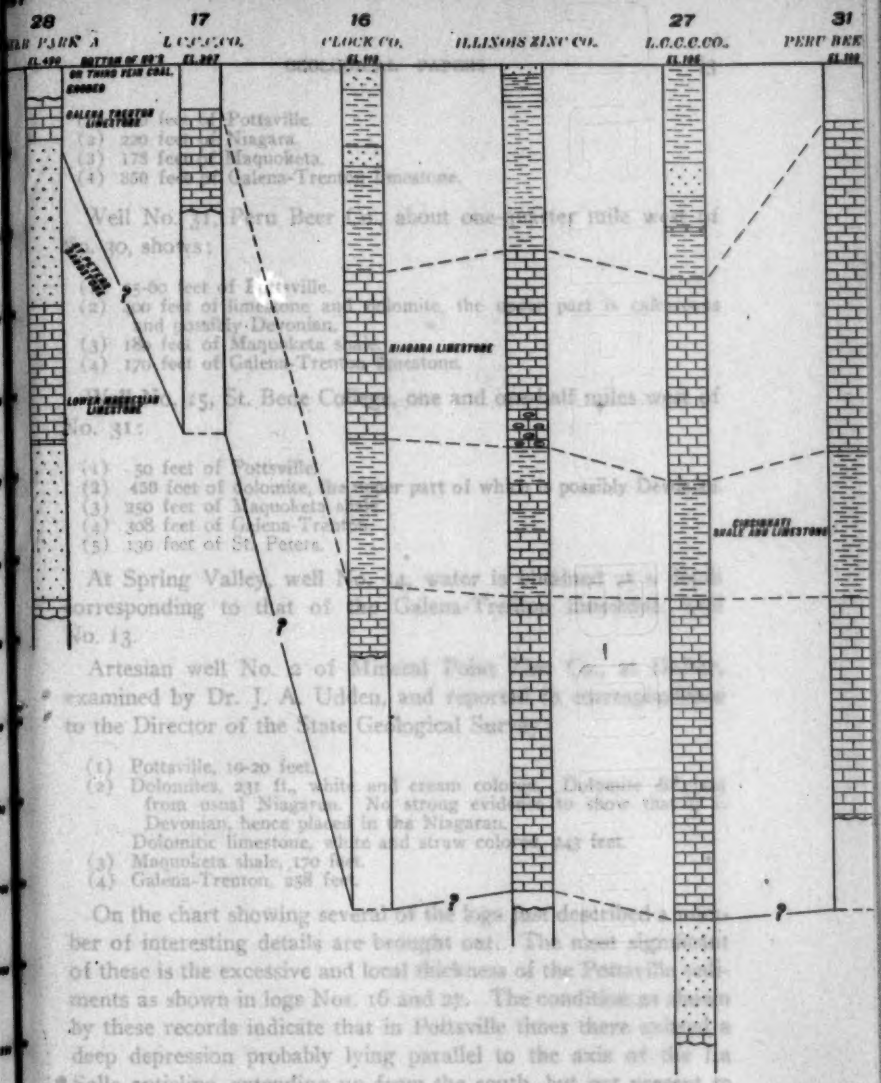


Chart Showing the Logs of Eleven Drill Holes in the Vicinity of LaSalle.

Chart Showing the Logs of Eleven
Drill Holes in the Vicinity of LaSalle.

(1) 200 feet of Pottsville.
(2) 220 feet of Niagara.
(3) 178 feet of Maquoketa.
(4) 350 feet of Galena-Trenton limestone.

Well No. 31, Peru Beer Co., about one-quarter mile west of No. 30, shows:

(1) 55-60 feet of Pottsville.
(2) 400 feet of limestone and dolomite, the upper part is calcareous and possibly Devonian.
(3) 180 feet of Maquoketa shale.
(4) 170 feet of Galena-Trenton limestone.

Well No. 15, St. Bede College, one and one-half miles west of No. 31:

(1) 50 feet of Pottsville.
(2) 450 feet of dolomite, the upper part of which is possibly Devonian.
(3) 250 feet of Maquoketa shale.
(4) 308 feet of Galena-Trenton.
(5) 130 feet of St. Peters.

At Spring Valley, well No. 14, water is obtained at a depth corresponding to that of the Galena-Trenton limestone, well No. 13.

Artesian well No. 2 of Mineral Point Zinc Co., at DePue, examined by Dr. J. A. Udden, and reported in correspondence to the Director of the State Geological Survey:

(1) Pottsville, 10-20 feet.
(2) Dolomites, 231 ft., white and cream colored. Dolomite different from usual Niagaran. No strong evidence to show that it is Devonian, hence placed in the Niagaran.
Dolomitic limestone, white and straw colored, 243 feet.
(3) Maquoketa shale, 170 feet.
(4) Galena-Trenton, 258 feet.

On the chart showing several of the logs just described a number of interesting details are brought out. The most significant of these is the excessive and local thickness of the Pottsville sediments as shown in logs Nos. 16 and 27. The condition as shown by these records indicate that in Pottsville times there existed a deep depression probably lying parallel to the axis of the La Salle anticline, extending up from the south, but not present to the west, as is shown by the thinning out of the formation in that direction. The second noteworthy feature is the thinning of the Niagara limestone where the Pottsville is thickest. This seems to indicate that the depression or basin in which the Pottsville sediments were deposited was not due to down faulting or folding, but to extensive erosion in the Niagara and Devonian limestone. In pre-Pottsville times there apparently existed in the

vicinity of La Salle, within a distance of one-quarter of a mile relief as great as 200 feet. A third point brought out by the chart relates to the source of the water supply. It is seen that almost all the wells obtain water not from the St. Peter sandstone, but from the Galena-Trenton limestone, a condition which has not been generally recognized heretofore for this part of the State.

For the sake of comparison, the log of a well recently drilled at Deer Park, which lies on or just east of the anticline, appears as No. 28, plate II. The succession shown by this log is very different from that shown in the logs to the right. The upper limestone, of which only a part is left, is the Trenton limestone outcropping along the banks of the Vermilion River. Below this lies about 200 feet of St. Peter sandstone. This is followed by 180 feet of Lower Magnesian or Shakopee limestone. This lies above a rather massive sandstone of about 200 feet in thickness, probably the New Richmond sandstone. The well penetrates about twenty feet of limestone below the New Richmond.

A further reason for introducing this log is for the sake of showing the difference in the stratigraphic conditions on the two sides of the anticline, and the possibility of confusing the St. Peter sandstone and New Richmond sandstone. East of the anticline the upper sandstone is eroded in the Illinois River bottom about Utica, hence the lower sandstone is often reported as St. Peter. Furthermore, the record of this well shows us the character of strata that would probably be encountered in deeper drilling west of the fold.

PLATE III.

In order that the local condition existing in the vicinity of La Salle may be more clearly understood, a cross-section has been prepared, extending from Rock Island to Joliet, showing structural conditions in northern Illinois, and the stratigraphical conditions from the Lower Magnesian formation to the "Coal Measures." The source of the data shown on this chart is partly from published articles by Dr. Udden, including the World's Fair cross-section and the Rock Island section in the seventeenth Annual Report of the Federal Survey, and partly from data in the files of the State Survey.

To sum up briefly what it is desired to show by the chart: (1) The general occurrence of the same strata having somewhat the same thickness on the two sides of the anticline, so far as they

THIS CHART WILL BE THE FIRST CHART
APPEARING AT THE END OF THIS FILM

have not been removed by erosion. It will be noticed, however, that the eastern Maquoketa is considerably thinner than the western. (2) The amount of the displacement of the La Salle anticline. The logs showing the full extent of this displacement are Nos. 15 and 17a. In both cases we have data on the bottom of St. Peter and top of the Lower Magnesian limestone. The Lower Magnesian limestone, as it is exposed in the bluff above well No. 17a, reaches practically to the base of the St. Peter sandstone, inasmuch as the top of the limestone contains the oölitic flints that mark the contact between the St. Peter and Lower Magnesian. The total displacement as indicated by these two wells is 1,500 feet. (3) The time and amount of the displacement. Inasmuch as coal veins are probably laid down on horizontal surfaces, and as coal No. 2, or third-vein, extends completely across the anticline in places, and, in fact, as the complete "Coal Measure" section near La Salle is affected by the disturbance, it seems unquestionable that the final folding is post-Pennsylvanian. The amount of this displacement is about 500 feet. As the coal beds dip slightly toward the fold on the west and away from it on the east, there has probably been movement on both sides.

The fact that there have been two movements shows in actual outcrop at Split Rock, near La Salle, and elsewhere along the anticline where the "Coal Measures" can be seen lying against the St. Peter sandstone. The former has a dip of twelve or fifteen degrees, the latter from twenty-five to thirty-five degrees.

The date of the fold seems to be determinable from a study of the contact of the Trenton-St. Peter formations and the Maquoketa-Galena formations east of the fold, as is shown by the cross-section (Plate III). The straight line marking the contact of the limestone and sandstone is a depositional surface and must have originally been flat. Therefore the uplift to the west ending in the anticlinal fold must have occurred in post-St. Peter time. Further attention is directed to the Trenton-Galena limestone east of the axis. It seems that in the well at Joliet, No. 25, the thickness of the Trenton-Galena is about normal, conforming with the condition west of the axis. It is thought that probably originally the limestone extended across the position of the fold. That this was the case seems probable because of its actual occurrence at present in places between the St. Peter sandstone and coal No. 2 near the axis of the anticline. The convergence of the lines of deposition of the Maquoketa on the Galena-Trenton and the Trenton on the St. Peter indicates a trunca-

tion of the limestone by erosion to a flat surface, upon which the shale was locally deposited. The convergence of these two lines of deposition seems reasonable proof that the age of the chief fold can be placed as post-Galena and pre-Maquoketa, or about contemporaneous with the formation of the Cincinnati arch. The displacement at the time amounted to about 1,000 feet.[1]

CORRELATION OF THE DEVONIAN SYSTEM OF THE ROCK ISLAND REGION.

W. ELMER EKBLAW.

This paper is an attempt to correlate the strata of the Devonian system of the northwest part of Illinois with those of the same system in other parts of the State and in adjacent States. It is the result of detailed field work done in that region in the summer of 1910, under the direction of Professor T. E. Savage, and in accordance with a general plan for the study of different formations of the State as formulated by Mr. F. W. DeWolf, director of the State Geological Survey.

Not much work has been done on the Devonian of this region. A. H. Worthen,[1] F. B. Meek,[2] James Shaw[3] and J. A. Udden[4] have devoted some attention to it, but no detailed account of its paleontology and stratigraphy has yet been given.

The Devonian exposures in northwest Illinois are confined to a rather narrow belt in Rock Island and Henry counties, bordering the bluffs of the Mississippi and Rock Rivers, and extending from a point opposite Montpelier, Iowa, to Green River, tributary to Rock River, and to Campbell's Island on the Mississippi River.

This narrow belt embraces the margin of the highlands fronting upon the flood plains of the Rock and Mississippi Rivers, and that portion of the flood plains immediately adjacent to the bluffs

[1] Since the presentation of the foregoing paper the well No. 27 at Cedar Point has been completed, so that the section at that place has been extended by the addition of 110 feet of Galena-Trenton limestone and 140 feet of St. Peter sandstone to the top of the Lower Magnesian limestone. The total depth is now 1,749 feet and 8 inches. These data have been included in the diagram on Plate II.

[1] Worthen, A. H., Geol. Survey of Illinois, Vol. I, 1866, pp. 120-122.

[2] Worthen, A. H., and Meek, F. B., Geol. Survey Illinois, Vol. II, 1866, p. 423. Idem. Vol. III, 1868, pp. 419-449.

[3] Worthen, A. H., and Shaw, James, Geol. Survey Illinois, Vol. V, 1873, pp. 217-234.

[4] Udden, J. A., Rept. Illinois Board of World's Fair Commissioners, 1893, pp. 117-177. Idem. Jour. Cincinnati Soc. Nat. Hist., Vol. XIX, 1896, pp. 93-94.

of the highlands. The bluffs rise boldly from eighty to 100 feet above the river flats. They are much dissected by small streams, which have cut through the drift of the Pleistocene, and, wherever the Pennsylvanian is present, through the shales and sandstones of that system, exposing the Devonian limestones below.

These small streams have comparatively steep gradients and a consequent erosive power of considerable strength. Wherever they cut through the limestones, they have developed rather narrow valleys with steep banks. The larger of these creeks are Fancy Creek, Case Creek and Mill Creek, all affording good exposures of Devonian strata in their banks.

The drift of the Pleistocene varies much in thickness, in some places scarcely covering the country rock, while on some of the hills, well borings reveal a depth of fifty feet of glacial material, which is probably all of Illinoian age. In the river valleys, material from the Wisconsin drift to the eastward has been deposited, and in the eastern portion of the area scattered localities of ridged loess and sand occur, which resemble in character those of the Iowan drift border. Usually the Pleistocene deposits rest upon those of the Pennsylvanian, but when the latter have been eroded the loess and drift cover the limestones of the Devonian age.

The Pennsylvanian shales and sandstones of this area, some seventy to 100 feet in thickness, belong to the Pottsville and Carbondale stages. They overlie the Devonian limestones, which at the time of deposition of the Pennsylvanian rocks formed the well dissected surface of the area. Well defined erosion valleys in the Devonian are filled with horizontally bedded shales, sandstones and occasional thin seams of coal. In a few separated areas these coal seams are thick enough for profitable working. The extent of the unconformity between the Pennsylvanian beds and the Devonian strata is revealed by the absence of the Upper Devonian, the entire Mississippian, and the lower portion of the Pottsville.

The absence of these strata may be due to the fact that the missing members were never deposited in this area, in consequence of land conditions prevailing here during their deposition elsewhere, but it is possible that at least a part of these members were laid down, and afterward eroded before the deposition of the overlying Pennsylvanian. The evidence which the very rough and broken Devonian surface affords tends to confirm this latter view.

The Devonian system of this area, the correlation of which is

the purpose of the present study, consists of limestones of Hamilton age, varying in thickness in the different exposures, from a few feet in the southwest corner of the area to over 100 feet in the Cady quarries of East Moline. They rest unconformably upon the Niagaran strata of the Silurian system, the unconformity in this case being more probably due to the prevalence of land conditions here, while the intervening members of the Silurian and Devonian system were being deposited in other localities.

The Silurian limestones upon which the Devonian beds rest unconformably belong to the Lockport stage of the Niagaran. They vary greatly in thickness, the maximum in this region being reported by Udden[1] as 364 feet. Their yellow color, dolomitic character and the presence of fragments of *Pentamerus oblongus* distinguish them from those of the Devonian. In this immediate area they are not exposed, their nearest outcrop occurring some miles farther north, near Port Byron.

The most westerly exposure of the Devonian limestone in this region is in the low bank of the Mississippi River directly across the river from Montpelier, Iowa. From this exposure eastward as far as the Green River, in Henry county, and northeastward to Campbell's Island in the Mississippi, the Hamilton limestone outcrops at many points in the banks and beds of the streams. The best exposures occur along Fancy Creek, Mill Creek and Case Creek. Other important exposures are those near the Water Power Company's dam, between Milan and Rock Island.

The Hamilton limestone is composed of several very definite members, readily distinguished by their fossils, or by their lithological characters. The lowest members are notably unfossiliferous, while some of the upper members are made up almost entirely of brachiopod shells, crinoid stems, or corals. The texture, jointing, and color of the various members also vary to such an extent that the different horizons can often be recognized by their lithological characters alone.

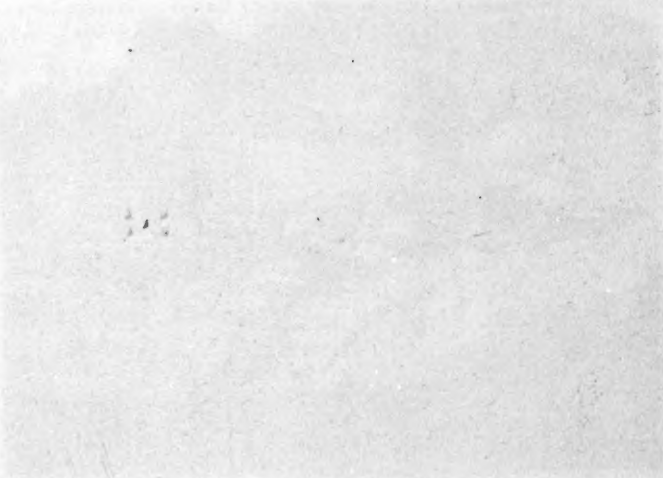
DETAILED SECTIONS OF THE DEVONIAN STRATA.

A continuous section from the lowest strata of the Devonian system exposed in the county, in the Cady quarry in East Moline, to the topmost stratum underlying the Pennsylvanian shales and sandstones along Fancy Creek, may be obtained by connecting up

[1] Udden, J. A., Rept. Illinois Board World's Fair Commissioners, 1893, p. 140.

Figure 1. View of that portion of the Cedar Valley limestone immediately below the *Acervularia davidsoni* Coral reef, which is the overhanging ledge at the top of this exposure along Mill Creek, Rock Island county, Illinois. The characteristic oblique jointing of some of the beds is quite distinct.

Figure 2. View of an outcrop of the lower portion of the Cedar Valley limestone along Mill Creek, Rock Island county, Illinois; the lowest block in the right-hand corner is the top of the Phillipsastrea ozne, which marks the uppermost layer of the Wapsipinicon stage.



the exposures in the Cady quarry, the outcrops along Mill Creek and the outcrops along Fancy Creek. Such a continuous section aggregates a thickness of more than 150 feet.

In the face of the Cady quarry 100 feet of brecciated, non-fossiliferous limestone is revealed, representing the lower portion of the Devonian section in this area. This exposure, which is accessible to careful examination and study, is described in the following section, designated N_2:

SECTION OF ROCKS EXPOSED IN THE CADY QUARRY.

		Feet.	In.
N_2n.	Loess and drift	10	
N_2m.	Gray to yellow, soft fissile shale	2	
N_2l.	Dark, carbonaceous shale	8	
N_2k.	Very hard, brown to red, ironstained limestone, containing many coralla of *Phillipsastrea billingsi* and shells of *Atrypa reticularis*	3	
N_2j.	Light gray to brown, much brecciated limestone, in layers 2 inches to 3 feet thick	30	
N_2i.	Gray, brecciated, very irregularly jointed limestone, in imperfect layers 4 inches to 3 feet thick, with occasional chert nodules	15	
N_2h.	Hard, gray, fine-grained, brecciated limestone, in layers 2 inches to 3 feet thick, with conspicuous vertical joints, and occasional ribbon-like veins of calcite	30	
N_2g.	Narrow band of hard, chocolate-colored, very fine-grained limestone, with crevices along joints and bedding planes filled with calcite		6
N_2f.	Hard, dark gray, fine-grained limestone, with crystals of calcite common along the joints	3	
N_2e.	Band of hard, almost black, coarse-grained limestone	1	
N_2d.	Soft, yellow, coarse-grained limestone, containing a distinct band of chert nodules near the middle	2	6
N_2c.	Soft, blue, sandy to shale limestone, containing much calcite.		6
N_2b.	Band of soft, dark gray to dark brown, fine-grained limestone, in layers 2 to 4 inches thick, and containing many calcite crystals	1	
N_2a.	Very hard, grayish brown, fine-grained brecciated limestone, in layers 4 inches to 3 feet thick. Lamination planes conspicuous in the lower portion. To the bottom	15	

In the foregoing section the shale members (N_2l and N_2m) represent the Pennsylvanian system, while the limestone members (N_2a to N_2k, inclusive), almost 100 feet in vertical thickness, belong to the Devonian. Of the Devonian members exposed in the quarry face, only the upper ten or fifteen feet may be seen anywhere else in Rock Island county. These lower 100 feet of Devonian strata are almost barren of fossils. Their correlation with the Devonian rocks in other regions must be made on the basis of their lithological character as revealed in this one exposure. The most distinctive of these characters is the brecciation which continues almost without interruption from the base to the top of the barren lower layers.

From this exposure in the Cady quarry the section may be continued upward in the Mill Creek outcrops, of which the lowest member, E_1a, corresponds to the upper portion of the member N_2j; and members E_1b and E_1c to the member N_2k.

The sections along Mill Creek comprise some of the most typical exposures of the Devonian rocks found in Rock Island county. With the exception of the section obtained in the Cady quarries, the Mill Creek sections, taken in their entirety, show the greatest thickness of Devonian strata, and, without exception, yield the greatest number of fossils.

The sections begin near the confluence of Mill Creek and Rock River, where the Fayette breccia appears, and extend continuously to the center of Sec. 25, T. 17 N., R. 2 W. A total vertical thickness of more than sixty feet of limestone is exposed in this section. A number of outcrops occur farther up the stream, but the strata exposed are included within the continuous section farther down the stream. The Mill Creek section marked E_1 is as follows:

SECTION OF STRATA EXPOSED ALONG MILL CREEK.

		Feet.	In.
E_1p.	Layer of gray, shelly, somewhat crystallized limestone, containing a large number of small shells of *Atrypa reticularis*	1	3

Zaphrentis sp. — *Schizophoria striatula*
Zaphrentis gigantea — *Reticularia fimbriata*
Athyris fultonensis — *Spirifer iowensis*
Atrypa reticularis — *Spirifer subvaricosus*

E_1o.	Coral limestone; *Acervularia davidsoni* coral reef	2	6
E_1n.	Brown limestone extending up to the top of the *Acervularia* coral reef	4	

Striatopora rugosa — *Atrpa reticularis*
Cyclotrypa communis — *Chonetes scitulus*
Cystodictya hamiltonensis — *Cranæna iowensis*
Euspilopora barrisi — *Cyrtina umbonata*
Fenestella vera — *Pentamerella dubia*
Fistulipora monticulata — *Spirifer subvaricosus*
Hemitrypa tenera — *Spirifer euryteines*
Orbignyella tenera — *Spirifer iowensis*
Reteporina hamiltonensis — *Stropheodonta demissa*
Semicoscinium rhombicum — *Stropheodonta perplana*
Platyceras sp.

E_1m.	Brown, fine-grained somewhat crystalline and crinoidal limestone, weathering into slabs 2 to 3 inches thick, and yielding the following fossils	5	

Eridotrypa appressa — *Schuchertella chemungensis*
Atrypa reticularis — *Spirifer euryteines*
Cranæna iowensis — *Spirifer iowensis*
Gypidula comis — *Spirifer subvaricosus*
Reticularia fimbriata — *Stropheodonta demissa*
Schizophoria striatula — *Stropheodonta perplana*
Phacops rana

		Feet.	In.
E_4l.	Soft, yellowish, fine-grained impure limestone, very shaly and shelly, weathering into thin bands. Pelecypods are particularly numerous in this member	4	6

Cyclotrypa collina
Cyclotrypa communis
Fistulipora monticulata
Orbignyella monticula
Atrypa reticularis
Chonetes scitulus
Cyrtina umbonata
Pholidostrophia iowensis
Spirifer asper
Spirifer euryteines
Spirifer iowensis
Spirifer subvaricosus
Strophеodonta demissa
Strophеodonta perplana
Platyceras dumosus
Actinopteria decussata
Cypricardella bellistriata
Goniophora sp.
Modiola sp.
Modiomorpha concentrica
Mytilops praecedens
Mytilarca sp.
Paleoneilo cf. plana
Paracyclas elliptica
Ptychopteria sp.
Sphenotus sp.

E_4k. Soft, yellowish, impure and shaly limestone. Joint planes nearly vertical and close together. Stratification is thin, the rock weathers readily 5

Cyathophyllum sp.
Striatopora rugosa
Spirorbis angulatus
Cyclotrypa collina
Cyclotrypa communis
Cystodictya hamiltonensis
Eridophyllum appressa
Euspilopora barrisi
Fenestella vera
Fistulipora monticulata
Orbignyella monticula
Semicoscinium rhombicum
Atrypa reticularis
Chonetes scitulus
Cranæna iowensis
Pholidostrophia iowensis
Roemerella grandis
Schizophoria striatula
Spirifer asper
Spirifer bimesialis
Spirifer euryteines
Spirifer iowensis
Spirifer subvaricosus
Cypricardinia indenta
Paleoneilo cf. plana
Gomphoceras ajax
Phacops rana

E_4j. Dark-gray to yellowish-gray, rather impure limestone, weathering rather easily. Jointing characteristically oblique 4

Ceratopora sp.
Cystiphyllum sp.
Streptelasma rectum
Spirorbis angulatus
Cyclotrypa collina
Cyclotrypa communis
Eridotrypa appressa
Fistulipora monticulata
Hederella filiformis
Orbignyella monticula
Petalotrypa compressa
Rhombopora sulcifera
Semicoscinium rhombicum
Ambocoelia umbonata
Atrypa hystrix
Atrypa reticularia
Atrypa spinosa
Chonetes scitulus
Cranæna iowensis
Cranaena romingeri
Crania sheldoni
Cyrtina hamiltonensis, var. *recta*
Cyrtina umbonata
Pentamerella dubia
Pholidostrophia iowensis
Schizophoria striatula
Spirifer asper
Spirifer euryteines
Spirifer iowensis
Spirifer subvaricosus
Strophеodonta demissa
Strophеodonta perplana

E_4i. Rather soft, gray to yellowish, impure limestone, in rather thick layers which weather easily and show oblique jointing 5

Streptelasma rectum
Cyclotrypa communis
Cystodictya hamiltonensis
Cyclotrypa collina
Fenestella vera
Fistulipora monticulata
Cranæna iowensis
Crania sheldoni
Cyrtina umbonata
Gypidula comis
Pentamerella dubia
Pholidostrophia iowensis

	Feet.	In.

Hemitrypa tenera — *Productella subalata*
Orbignyella monticula — *Reticularia fimbriata*
Semicoscinium rhombicum — *Schizophoria striatula*
Spirorbis sp. — *Spirifer asper*
Athyris fultonensis — *Spirifer iowensis*
Atrypa hystrix — *Spirifer euryteines*
Atrypa reticularis — *Spirifer subvaricosus*
Chonetes scitulus — *Stropheodonta demissa*
Stropheodonta perplana

E_1h. Gray, thinly-bedded, rather impure limestone, weathering easily. Fossils rather numerous..... 2 6

Ceratopora sp. — *Crœnæna iowensis*
Streptelasma rectum — *Cyrtina umbonata*
Cyclotrypa communis — *Pentamerella dubia*
Cystodictya hamiltonensis — *Schizophoria striatula*
Eridotrypa appressa — *Productella subalata*
Euspilopora barrisi — *Reticularia fimbriata*
Fistulipora monticulata — *Spirifer asper*
Hemitrypa tenera — *Spirifer bimesialis*
Orbignyella monticula — *Spirifer euryteines*
Petalotrypa compressa — *Spirifer iowensis*
Rhombopora subannulata — *Spirifer subvaricosus*
Semicoscinium rhombicum — *Stropheodonta demissa*
Atrypa hystrix — *Stropheodonta perplana*
Atrypa reticularis — *Tentaculites bellulus*
Chonetes scitulus — *Phacops rana*

E_1g. Gray, fine-grained, easily-eroded, impure limestone, shaly in places. Fossils not numerous but varied..... 2 6

Streptelasma rectum — *Chonetes scitulus*
Cyclotrypa communis — *Crania sheldoni*
Cystodictya hamiltonensis — *Lingulodiscina marginalis*
Fenestella vera — *Pholidostrophia iowensis*
Fistulipora monticulata — *Productella subalata*
Hemitrypa tenera — *Reticularia fimbriata*
Orbignyella monticula — *Schizophoria striatula*
Semicoscinium rhombicum — *Schuchertella chemungensis*
Athyris fultonensis — *Spirifer subvaricosus*
Atrypa hystrix — *Spirifer iowensis*
Atrypa reticularis — *Stropheodonta demissa*
Stropheodonta perplana

E_1f. Yellowish, impure, richly fossiliferous limestone.....

Streptelasma rectum — *Chonetes scitulus*
Cyclotrypa communis — *Cyrtina umbonata*
Cystodictya hamiltonensis — *Schizophoria striatula*
Fenistella vera — *Schuchertella chemungensis*
Fenestropora occidentalis — *Spirifer iowensis*
Hemitrypa tenera — *Spirifer subvaricosus*
Orbignyella monticula — *Stropheodonta demissa*
Rhombopora subannulata — *Stropheodonta perplana*
Semicoscinium rhombicum — *Bellerophon pelops*
Atrypa hystrix — *Actinopteria decussata*
Atrypa reticularis — *Phacops rana*

E_1e. Layer of hard, dark gray limestone..... 1 8

Stylodictyon expansum — *Schizophoria striatula*
Atrypa hystrix — *Spirifer bimesialis*
Atrypa reticularis — *Spirifer euryteines*
Cyrtina hamiltonensis — *Spirifer subvaricosus*
Pholidostrophia iowensis — *Stropheodonta demissa*

Feet. In.

E_1d. Layer of yellowish, rather shaly limestone which weathers readily. Fossils resembling those of E_1e..... 9

Cyathophyllum sp.
Cystiphyllum cf. *americanum*
Streptelasma simplex
Atrypa hystrix
Atrypa reticularis
Atrypa spinosa
Cranæna iowensis
Productella subalata
Schizophoria striatula
Spirifer iowensis
Stropheodonta demissa
Stropheodonta perplana
Platyceras dumosum
Pleurotomaria lucina
Gomphoceras ajax

E_1c. Outcrop under and just south of the Rock Island Ry. bridge, in the S.E. ¼ sec. 24, T. 17 N., R. 1 W. Very hard, fine-grained limestone containing many corals. May be designated as the *Phillipsastrea* horizon..... 1 3

Astraeospongia hamiltonensis
Alveolites goldfussi
Acervularia davidsoni
Acervularia profunda
Ceratopora sp.
Cladopora palmata
Cladopora sp.
Craspedophyllum archiaci
Cyathophyllum sp.
Cystiphyllum americanum
Favosites alpenensis
Favosites hamiltonensis
Favosites placenta
Heliophyllum halli
Phillipsastrea billingsi
Streptelasma simplex
Zaphrentis sp.
Hemitrypa tenera
Orbignyella monticula
Atrypa hystrix
Atrypa reticularis
Cranæna romingeri
Gypidula comis
Nucleospira ventricosa
Productella subalata
Reticularia subundifera
Schizophoria striatula
Spirifer eurytcines
Spirifer iowensis
Stropheodonta demissa
Bellerophon pelops
Pleurotomaria lucina
Gomphoceras sp.

E_1b. Stratum of hard, gray limestone, just above the breccia, and below *Phillipsastrea* zone, containing the fossils..... 1 3

Zaphrentis sp.
Athyris fultonensis
Atrypa hystrix
Atrypa reticularis
Cranæna iowensis
Cyrtina hamiltonensis
Pentamerella dubia
Pholidostrophia iowensis
Productella subalata
Reticularia fimbriata
Spirifer subvaricosus
Stropheodonta demissa
Bellerophon pelops
Pleurotomaria lucina
Gomphoceras

E_1a. Outcrop in bed of Mill Creek, one-half mile east of Milan, north and south of wagon bridge. Dark-gray, fine-grained, much brecciated limestone, bearing no fossils..... 10

The members of the section from the bottom up to the *Acervularia davidsoni* coral reef are clearly separable into two general divisions: the lower, softer and more yellow is thinly stratified; the upper, harder and more brown, is in thicker layers. In both portions the jointing is not nearly so close together and is more nearly perpendicular to the bedding planes than in the members E_1g to E_1j, inclusive. The latter members are distinctly and characteristically obliquely jointed, and shattered and broken into small, very sharp and angular blocks.

The uppermost member of the Mill Creek section, E_1p, may be

readily correlated directly with the member D_8h of the Fancy Creek section, by means of the fossils. A number of intervening exposures substantiate this correlation. The Fancy Creek section is as follows:

		Feet.	In.
D_8h.	Very hard, iron-stained, fine-grained limestone, containing..		10
	Stropheodonta concava *Stropheodonta perplana*		
D_8g.	Iron-stained, fine-grained, slightly crystalline limestone.....	1	
	Athyris fultonensis *Spirifer asper*		
	Cranæna iowensis *Stropheodonta demissa*		
D_8f.	Hard, slightly iron-stained, fine-grained limestone with numerous coralla of		2
	Zaphrentis gigantea		
D_8e.	Hard, dark-gray, almost crystalline limestone, slightly stained by iron. Many fossils.....	1	
	Stylodictyon expansum *Lingulodiscina marginalis*		
	Cladopora prolifica *Pugnax* sp.		
	Zaphrentis sp. *Reticularia fimbriata*		
	Athyris fultonensis *Spirifer iowensis*		
	Cranæna sp. *Spirifer subvaricosus*		
	Bellerophon pelops		
D_8d.	Very hard, banded, black and gray, limestone with numerous stromatoporoids		4
	Cladopora palmata *Zaphrentis* 2 sp.		
	Cladopora prolifica *Spirifer iowensis*		
	Stropheodonta demissa		
D_8c.	Rather soft, coarse-grained limestone, with many fossils.....		8
	Atrypa reticularis *Spirifer iowensis*		
	Schizophoria striatula *Stropheodonta demissa*		
	Spirifer euryteines *Phacops rana*		
D_8b.	Bluish to brownish, irregularly-bedded, fine-grained, limestone with band of large *Atrypa reticularis* near middle. The fossils are.....	3	6
	Atrypa reticularis *Stropheodonta demissa*		
	Cranæna iowensis *Edmondia* sp.		
D_8a.	Gray, locally iron-stained, shelly and shaly limestone, containing *Spirifer iowensis* and numerous small *Atrypa reticularis* throughout. *Athyris fultonensis* and *Spirifer euryteines* are common near the top.....	3	
	Streptelasma rectum *Schizophoria striatula*		
	Orbignyella monticula *Spirifer asper*		
	Athyris fultonensis *Spirifer euryteines*		
	Atrypa reticularis *Spirifer subvaricosus*		
	Cranæna iowensis *Stropheodonta demissa*		
	Cyrtina umbonata, var. *alta* *Sropheodonta perplana*		

From the foregoing sections, which include all of the Devonian strata that are exposed in Rock Island county, a generalized section of the Devonian rocks in this area may be constructed. The lowest members of this generalized section, including all the brecciated beds, are represented in the Cady quarry exposure in East Moline. The uppermost member of the Cady quarry section, the Phillipsastrea zone, N_2k, is equivalent to E_1c of the

Mill Creek section. Consequently the Mill Creek section becomes a direct upward continuation of the Cady quarry section. The uppermost member of the Mill Creek section, E_1p, which contains the numerous small shells of *Atrypa reticularis,* is equivalent to the lowest member of the Fancy Creek section D_8a, of which the topmost layer, D_8h, represents the uppermost rocks of the Devonian system found in Rock Island county.

The aggregate thickness of the Devonian rocks in Rock Island county is thus found to be slightly more than 150 feet, of which the lower 100 feet are exposed only in the Cady quarry at East Moline.

LIST OF FOSSILS.

A list of the fossils collected from the Devonian strata in Rock Island county is given in full below. The names of those which occur in the Devonian of Iowa are indicated by "x" in the first column; those which occur in Jackson and Union counties by an "x" in the second column; those which occur in New York and the eastern province of the Hamilton by an "x" in the third column; those which occur in Wisconsin by an "x" in the fourth column; and those which occur in Jersey and Calhoun counties, Illinois, by an "x" in the fifth column.

The list of fossils occurring in the Devonian strata of Iowa was compiled from the reports of the Iowa Geological Survey, and since these reports are not especially paleontological, the list is probably incomplete; the list of the fossils of Jackson and Union counties, Illinois, from unpublished lists furnished by Professor Savage; the list of the fossils from New York and the Eastern Province of the Hamilton, from State Reports and various other sources; the list of the fossils from Wisconsin, from Cleland's[1] report of 1911; and the list from Jersey and Calhoun counties, from an unpublished thesis by J. G. Hutton.

	1	2	3	4	5
Astraeospongia hamiltonensis, Meek and Worthen	*				*
Caunopora incrustans, Hall and Whitfield	*				
Stromatopora sp.					
Stylodictyon expansum, Hall and Whitfield	*				
Acervularia davidsoni, Edwards and Haime	*		*	*	*
Acervularia profunda, Hall	*				*
Alveolites goldfussi, Billings	*		*		*
Amplexus sp.					
Ceratopora sp.					
Cladopora cryptodens, Billings	*		*		*
Cladopora prolifica, Hall and Whitfield	*				

[1] Cleland, H. F., Wisconsin Geol. and Nat. Hist. Survey Bull., No. XXI, 1911. The fossils and stratigraphy of the middle Devonian of Wisconsin.

	1	2	3	4	5
Cladopora palmata, Hall and Whitfield	*				
Craspedophyllum archiaci, Billings	*	*	*		
Cyathophyllum sp.					
Cystiphyllum cf. *americanum*, Edwards and Haime	*	*	*	*	*
Favosites alpenensis, Winchell	*			*	*
Favosites placenta, Rominger	*		*		
Heliophyllum halli, Edwards and Haime	*	*	*		
Phillipsastrea billingsi, Calvin	*				
Streptelasma rectum, Hall			*		
Streptelasma simplex, Hall			*		
Striatopora rugosa, Hall	*				
Zaphrentis gigantea, Lesueur			*		
Zaphrentis sp.					
Spirorbis angulatus, Hall			*		
Cyclotrypa collina, Ulrich	*		*		
Cyclotrypa communis, Ulrich	*				
Cystodictya hamiltonensis, Ulrich	*		*	*	
Eridotrypa appressa, Ulrich	*			*	
Euspilopora barrisi, Ulrich	*				
Fenestella vera, Ulrich	*			*	
Fenestrapora occidentalis, Ulrich	*				
Fistulipora stricta, Ulrich	*				
Fistulipora monticulata, Ulrich	*			*	
Hederella filiformis, Billings	*			*	
Hemitrypa tenera, Ulrich	*				
Meekopora stellifera, Rominger	*		*		
Orbignyella monticula, White	*			*	
Orbignyella tenera, Cleland				*	
Petalotrypa compressa, Ulrich	*			*	
Reteporina hamiltonensis, Ulrich	*			*	
Rhombopora subannulata, Ulrich	*				
Rhombopora sulcifera, Ulrich	*				
Semicoscinium rhombicum, Ulrich	*			*	
Ambocœlia umbonata, Conrad		*	*		
Athyris fultonensis, Swallow	*	*	*	*	*
Atrypa hystrix, Hall	*	*	*	*	*
Atrypa aspera occidentalis, Hall	*				
Atrypa reticularis, Linnæus	*	*	*	*	*
Atrypa spinosa, Hall	*	*	*		*
Chonetes scitulus, Hall	*	*	*		
Cranæna iowensis Calvin	*			*	*
Cranæna romingeri, Hall	*	*	*		
Crania sheldoni, White	*		*		
Cyrtina hamiltonensis, Hall	*	*	*	*	*
Cyrtina hamiltonensis recta, Hall	*	*	*	*	*
Cyrtina umbonata, Hall	*				*
Gypidula comis, Owen	*			*	
Lingulodiscina marginalis, Whitfield				*	
Nucleospira concinna, Hall	*	*	*	*	
Nucleospira ventricosa, Hall			*		
Orbiculoidea telleri, Cleland				*	
Orbiculoidea wardi, Cleland				*	
Pentamerella dubia, Hall	*				
Pholidostrophia iowensis, Owen	*	*	*	*	*
Productella subalata, Hall	*				*
Pugnax sp.					
Reticularia fimbriata, Conrad	*		*	*	
Reticularia subundifera, Meek and Worthen	*				*
Rhipidomella vanuxemi, Hall	*		*	*	
Rœmerella grandis, Vanuxem			*		
Schizophoria striatula, Schlotheim	*		*	*	*
Schuchertella chemungensis, Conrad	*		*		

			Feet.		In.
Spirifer asper, Hall	*		*	*	*
Spirifer bimesialis, Hall	*		*		
Spirifer euryteines, Owen	*			*	*
Spirifer iowensis, Owen	*			*	*
Spirifer subvaricosus, Hall and Whitfield	*			*	*
Stropheodonta concava, Hall	*	*	*		*
Stropheodonta demissa, Conrad	*	*	*	*	*
Stropheodonta perplana, Conrad	*		*	*	
Bellerophon pelops, Hall	*		*		
Phanerotinus exiguus, Kindle	*		*	*	
Platyceras dumosum, Conrad		*		*	*
Pleurotomaria lucina, Hall			*		
Tentaculites bellulus, Hall		*	*	*	*
Actinopteria decussata, Hall		*	*		
Aviculopecten sp.					
Conocardium cuneus altum, Keyes	*	*			
Cypricardella bellistriata, Conrad	*		*	*	
Cypricardinia indenta, Conrad	*	*	*	*	*
Edmondia sp.					
Goniophora sp.					
Modiola sp.					
Modiomorpha concentrica, Hall			*		*
Mytilarca trigonale, Cleland				*	*
Mytilops præcedens, Hall	*		*		
Paleoneilo cf. plana, Hall	*	*	*	*	*
Paracyclas elliptica, Hall	*	*	*		*
Paracyclas lirata, Conrad	*	*	*		*
Pterinopecten sp.					
Ptychopteria eucrate, Hall			*		
Ptychopteria sao, Hall			*		
Sphenotus sp.					
Gomphoceras ajax, Hall	*		*		
Gyroceras pratti, Barris	*		*		
Dalmanites barrisi, Hall	*				
Phacops rana, Green	*	*	*	*	*
Prætus cf. occidens, Hall					

CONCLUSION.

A study of the foregoing list of fossils found in the Devonian strata in Rock Island county leaves no doubt that they are more closely related to the fauna of the Dakotan or Northwest province of the Hamilton division of the Devonian than to the New York or Eastern province. Of the total number of ninety-seven species determined, eighty-one, or 83 per cent, are found elsewhere in the Dakotan province, and of these eighty-one species, forty-two, or 51 per cent, are found exclusively in this province. Of the fifty-five species occurring also in the Eastern province, all are widespread forms, and have a general distribution, none being distinctively Eastern species. Of the "Standard list of dominant species for the New York-Ontario province" (Eastern Middle Devonian), which Williams[1] has established, only two, *Phacops*

[1] Williams, H. S., Am. Jour. Sci., Vol. XIV, 4th ser., 1912.

rana and *Ambocoelia umbonata*, occur in the Dakotan province, and both of these are cosmopolitan forms.

Of the forty-one species listed by Hutton[2] from Jersey and Calhoun counties, thirty-five, or 87 per cent, are found in the Rock Island county Devonian strata, while only twenty-five, or 16 per cent, of the 151 species listed by Savage from the Hamilton strata of Jackson and Union counties of southwestern Illinois are found in the Rock Island county strata, and nearly all of the 151 species are of the Eastern province. Therefore the close relationship of the Devonian strata of Jersey and Calhoun counties and those of Rock Island county to those of the Dakotan province is conclusive proof that both belong to this province, of which they constitute the southward and eastward extension; while the similarity of the fauna of the Hamilton strata of Jackson and Union counties to that of the New York or Eastern province unquestionably proves that they form a part of that province. The land barrier shown as extending across central Illinois in Schuchert's paleogeographic map of late Hamilton time, known as the Kankakee axis, separated the basin in which the deposits of the Eastern province (including Union and Jackson counties in southwestern Illinois) were laid down, from the basin in which the Hamilton strata of Rock Island and Jersey and Calhoun counties were deposited.

The fauna of the Wisconsin Hamilton is a mixture of the faunas of the Eastern and of the Northwest or Dakotan provinces. These forms lived in an arm of the sea in which the waters of the two basins mingled. Only thirty-six, or 37 per cent, of the ninety-seven species found in Rock Island county also occur in Wisconsin, and of these thirty-six species, nineteen, or 52 per cent, occur only in the Dakotan province, while seventeen, or 48 per cent, occur in both provinces.

The Hamilton strata of the Dakotan province in Rock Island county comprise equivalents of the Wapsipinicon and Cedar Valley stages of the Hamilton in Iowa. All of those strata below and including the Phillipsastrea bed are the equivalent of the Lower and Upper Davenport divisions of the Wapsipinicon stage of the Iowa strata, the lithological characters (of which brecciation is the most conspicuous) and the stratigraphic position of these strata being the basis of correlation. The Hamilton strata

[2] Hutton, J. G. Thesis for degree of Master of Science in Geology in the Graduate School of the University of Illinois. The stratigraphy of the Devonian rocks of Calhoun and Jersey counties, Illinois, with a preliminary discussion of the physiography of the region.

in Rock Island county, above the level of the Phillipsastrea bed, are lithologically and faunally similar to the Cedar Valley strata of Iowa, and may be correlated with certainty with the rocks of that stage.

According to Hutton's unpublished thesis, the limestones of Jersey and Calhoun counties, Illinois, are of the same age as those of the Cedar Valley stage, in Iowa, lying between the Stromatopora reef and the *Acervularia davidsoni* zone. Consequently they may be correlated with the equivalent portion of the Rock Island county section. The upper portion of the Rock Island county strata may likewise be correlated with the Hamilton limestone of northern Missouri, which corresponds in time with the rocks of the Cedar Valley stage in Iowa.

The Rock Island county Devonian limestones are a continuation eastward of the Wapsipinicon and Cedar Valley stages of Iowa. They represent the same general period of time and the same general conditions of deposition.

A TUFA DEPOSIT NEAR DANVILLE, ILLINOIS.

CHARLES E. DECKER.

While conducting an excursion from the University of Illinois, last summer, along the Vermilion River, in the vicinity of Danville, some large fragments of tufa were discovered near the base of a slope. Search for the origin of these fragments led to the discovery of an extensive tufa deposit farther up the hill. This deposit is on the farm of Mrs. Mary A. Kistler, on the north side of the Vermilion River, one-half mile northeast of the confluence of the Middle and Salt Forks, and one and one-half miles southwest of Hillery. The upper part of the tufa borders on the lower edge of a spring basin (Fig. 1) in which the spring issues sixty feet back from this edge.

The tufa is of special interest, because no other work of this kind by ground-water is known in this region. Solution on a large scale is shown by the extensive caves of southwestern Indiana, but the nearest tufa deposits known to the writer are those noted by Grant and Burchard[1] in southwestern Wisconsin along the Platte, Little Platte, Grant and Mississippi Rivers.

[1] Lancaster-Mineral Point Folia, p. 9.

In form the deposit resembles an alluvial fan. It extends down the hill about 150 feet and widens from a few feet across at the top to about 150 feet in width at the base. Accordingly, its approximate areal extent is 10,000 square feet. The thickness may be seen along its eastern edge, where it is exposed in the side of a gully throughout its entire length. Here the thickness varies from two to four feet. If an average thickness of three feet be taken for the entire deposit, it comprises about 30,000 cubic feet.

The composition is almost pure calcium carbonate ($CaCO_3$). It contains little extraneous material except along the base, where it filled in the spaces in the underlying glacial gravels, thus including some of them in its lower part.

The included fossils comprise leaves and shells. The leaves are large with open venation and resemble those of the Sycamore or Sugar Maple, which are the oldest trees now growing in the vicinity. Locally, the leaves are so abundant that a rude cleavage is developed in the tufa parallel to their flat faces. The shells are all gastropods with a spire of medium height. Those of a single species, *Polygyra elevata*,[2] say, were scattered in great numbers over the surface of the deposit, and a single specimen was found within it.

The texture of the tufa varies from porous and open to compact. In some parts it shows a botryoidal or mammilary structure, while in others a delicately branching, moss-like structure may be seen. In still other parts a cleavage is developed, as noted above, due to the presence of numerous fossil leaves.

The surface of the tufa is mostly covered by a fine calcareous dust, though some larger fragments of the material lie scattered about. As indicated by the dust, the surface is devoid of smaller vegetation, but it is sparsely covered with bushy trees of Black Locust, Hawthorn, Elm, Willow and Apple.

The topographic relation of the tufa to the spring suggests that it was deposited by the water issuing above it. However, these waters are not now depositing, but, instead, are degrading the earlier deposit. The spring flows at the rate of three-fourths of a gallon per minute. This water and that collected by the spring basin has cut a gully fifteen feet deep in the eastern edge of the tufa, and has carried much of it away. The west side of this gully is so white with calcareous dust and fragments of the tufa

[2] Identification by J. D. Hood.

Figure 1. Spring Basin. Water from the spring enters the gully (shown in Figure 2) at the left of A. A glacial conglomerate is exposed beneath the rail fence at the man's right and just outside the foreground.

Figure 2. Gully cut through east edge of tufa deposit. The bank at the left is white with the calcareous dust, and fragments of tufa lie among the sticks at the bottom.

that superficial observation gives the impression that the deposit extends to the bottom of the gully, as shown by Fig. 2.

With reference to the origin of the calcium carbonate ($CaCO_3$) it may be said that most calcareous deposits made by springs occur in limestone regions, but no limestone is known to exist in the vicinity of this deposit. Mine shafts to the north and the bluffs across the river to the south expose only a silicious shale. However, along the lower rim of the spring basin on either side of the outlet remnants of a glacial conglomerate are exposed, and one of these exposures is along the rail fence at Mr. Eaton's right in Fig. 1. This conglomerate is firmly cemented with calcium carbonate ($CaCO_3$). If the basin of the spring were at one time filled by a glacial conglomerate of which the present exposures are small remnants, an adequate source for the calcareous deposit would be furnished. Were the glacial conglomerate at one time much more extensive than now, the reduction to the present limited remnants would account for a decrease in calcium carbonate ($CaCO_3$) supplied to the spring, and hence explain the cessation of deposition of that substance from solution.

No very definite evidence of the age of the tufa was noted. The conglomerate, because of its highly indurated condition, doubtless belongs to a stage of glaciation as early as the Illinoisan. While the unindurated gravels beneath the tufa are similar to those overlying the conglomerate, and both of these gravel deposits probably are of Wisconsin age.[2] These considerations favor the idea that the tufa has been deposited since the Wisconsin Stage of Glaciation.

ON THE EARTHQUAKE OF JANUARY 2, 1912, IN THE UPPER MISSISSIPPI VALLEY.

ANTON D. UDDEN,

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On January 2, 1912, the northwestern part of Illinois and surrounding territory were visited by an earthquake. Immediately after the shock the author began to collect information concerning the effects of the disturbance. The description in this paper is based upon the accounts of the earthquake contained in seventy-

[2] Danville Folio, p. 1, et seq.

eight daily and weekly papers, and upon fifty-five letters from editors of newspapers. Information has been received from about 150 localities in and about the affected area.

The distribution of intensities in an earthquake such as that which occurred on January 2 is conveniently studied by the so-called Rossi-Forel scale of intensity. According to this scale, intensities are denoted increasingly by the numerals from one to ten. The scale is not often seen in print, and since the author has made some additions to the scale, it has been inserted at the end of this paper.

The author believes that the data collected concerning this earthquake are sufficiently complete to determine with a fair degree of accuracy the intensities at about ninety-five cities. At thirty-five of these cities the disturbance is described as being "not noticed," while for the remaining sixty the accounts are more or less complete. The following isoseismal chart of the earthquake is based upon the intensities as determined for these cities according to the Rossi-Forel scale.

It will be seen on the accompanying map that the intensities vary from one to six. The general appearance of the isoseismal

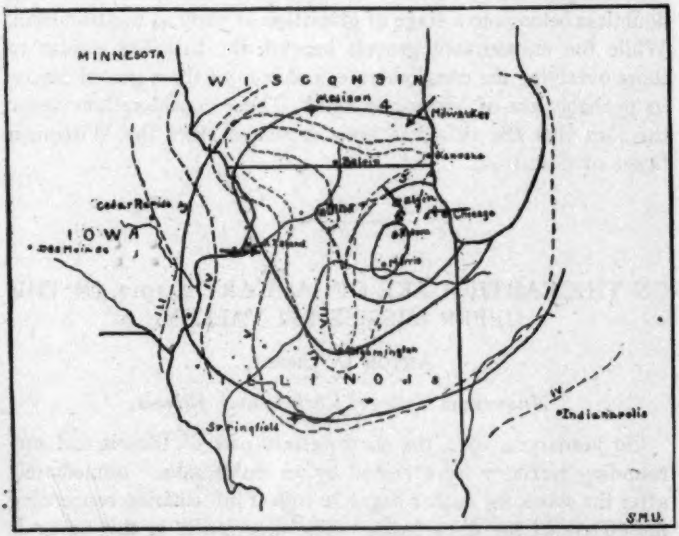


Figure 1. Map of earthquake of January 2, 1912. Full lines=isoseismals of January 2, 1912 earthquake. Broken lines=isoseismals of May 26, 1909 earthquake.

lines suggests that there was one distinct epicentre from which the waves spread in the form of ever-widening circles. The earthquake was most severe within the area enclosed by the isoseismal whose intensity is six. The cities in this area which report the most violent effects are Morris and Aurora, for which the intensities are more nearly seven than six.

While the principal epicentre is the one just described, there appears to be also a secondary epicentre whose intensity is five. This is at Dixon, Illinois, about fifty-five miles west of the first epicentre. With the data on hand it is difficult to determine whether this is a distinct epicentre of less intensity or whether Dixon should be included in the area enclosed by the isoseismal whose intensity is five. The dotted line indicates the direction which this isoseismal would take in the latter case. That there were two epicentres appears to be supported by observations on the number of shocks reported to have been felt at different localities. The majority of these observations state that there were two distinct shocks—one of greater intensity, preceded or followed by one of less severity.

Observations upon the directions of motion of the earthquake waves are reported from four different localities—Chicago, Milwaukee, Elgin and Rock Island. The directions are indicated on the map by means of arrows drawn through the respective cities. While the arrows do not intersect at a common point, yet in a general way they converge toward the region of greatest disturbance.

The area sensibly affected by this earthquake covers about 40,000 square miles. It is possible that the earthquake did not extend for any considerable distance beyond the limits of the sensible area. In a letter, Professor J. B. Goesse, S. J., states that the seismograph belonging to the meteorological observatory of the St. Louis University in St. Louis did not record any vibrations which could with certainty be referred to this earthquake disturbance. Francis J. Glover, S. J., of Brooklyn College, Brooklyn, New York, states that if their seismograph recorded the earthquake the record was obliterated by local disturbances caused by nearby railroad traffic.

The observations on the time of occurrence and duration of the earthquake do not warrant any deductions. The time of occurrence is variously stated from 10:15 to 10:35 a. m., while the reports on duration range from one second to three minutes.

It is interesting to compare this earthquake with the one which

occurred on May 26, 1909. The latter was more extensive and of greater severity than the one here described. This can readily be seen by referring to the isoseismal drawing of the earthquake of May 26, 1909, by Dr. J. A. Udden, in the Transactions of the Illinois State Academy of Science for 1910. In several instances newspapers have made statements comparing the intensity of the more recent earthquake to that of the former. The intensity for cities lying within the mesoseismal area of the recent earthquake is stated to be "equal to" or "more severe" than in the earlier earthquake. Cities lying beyond the mesoseismal area describe the earthquake as being less severe than that of May 26, 1909. These statements conform quite satisfactorily with the isoseismals of the two earthquakes.

The epicentres of the two disturbances are differently located, but the areas affected by both are substantially the same. By referring to the drawings it is seen that the isoseismals of each spread out from a nearly common center. The coincidence of these two earthquake areas can hardly be regarded as a matter of chance. It is probable that the two shocks were directly connected with a gradual readjustment of the same strata.

THE ROSSI-FOREL SCALE ACCORDING TO DUTTON.

1. Microseismic Shock: Recorded by a single seismograph or by seismographs of the same model, but not by several seismographs of different kinds; the shock felt by an experienced observer.

2. Extremely Feeble Shock: Recorded by several seismographs of different kinds; felt by a small number of persons at rest.

3. Very Feeble Shock: Felt by several persons at rest; strong enough for the direction or duration to be appreciable.

4. Feeble Shock: Felt by persons in motion; disturbance of movable objects, doors, windows, creaking of ceilings; *rattling of dishes.**

5. Shock of Moderate Intensity: Felt generally by everyone; disturbance, furniture, beds, etc., ringing of some door bells (old style door bells); *articles fall, dishes break.**

6. Fairly Strong Shock: General awakening of those asleep, general ringing of bells, oscillation of chandeliers; stopping of clocks, visible agitation of trees and shrubs; some startled persons leave their dwellings.

7. Strong Shock: Overthrow of movable objects, fall of plaster, ringing of church bells; general panic without damage to buildings.

8. Very Strong Shock: Fall of chimneys, cracks in the walls of buildings.

9. Extremely Strong Shock: Partial or total destruction of some buildings.

10. Shock of Extreme Intensity: Great disaster, ruins, disturbance of the strata, fissures in the ground, rock-falls from mountains.

The original data, newspaper clippings, letters, etc., upon which this paper is based have been left in the Denkmann Memorial Library of Augustana College, where they may be obtained by application to the Librarian.

NOTES ON SANGAMON COUNTY LIMESTONES.

A. R. Crook.

The following information was furnished by diamond drill cores from a drilling made some years ago at Divernon, sent two years ago to the State Museum and just made accessible for study and exhibition.

For stratigraphic investigation it is true that drill cores are small, are deficient in weathered fossils, and lack the prominent features of outcropping ledges. But they have the advantage of presenting for examination every foot of strata underlying a given point and showing the exact location of the various strata in relation to each other. While clays and soft shales are washed out by the water used in keeping the drill hole clean, their thickness is recorded and samples show their character.

Divernon is seventeen miles south of Springfield and about two miles from the south line of Sangamon County. The boring began at about 600 feet above sea level and ended at a depth of 604 feet. First it went through 9 feet of loess, 15 feet of "Illinoian" till and 16 feet of "Kansan" till, and at a depth of 40 feet reached the rock, a limestone. This limestone and all the subsequent strata encountered constitute the upper half of the

* The words in italics have been added by the author.

The accompany table shows the result of the examination:

	No.	Depth.	Thickness.	Color.	Streak.	H.	Toughness.	Residue.	Fossils.	Remarks.
Upper Production	1	40	5′	White, mottled	White	3.5	Tough	.5	Rare	Brecciated and recemented
	2	45	3′	Rusty	Gray	3.2	Tough	11	Fossils	Rusty
	3	58	4′	Drab	White	3	Tough	4.4	Few fossils ("Carlinville" L. S.?)	.....
	4	71	1′	Gray	White	3	Tough	4.5	Crinoids, Brachiopods (Productus)	Outcrops at Croll's Mill 8 M. S. of Springfield, Old State House constructed of it
	5	75	3′	Brown	Brown	...	Friable	40	.....	Sandy
	6	149	8″	Black	Black	3.1	Crumbly	17.5	Rich in fossils	Outcrops at Riverton, east of Springfield
	7	160	2′	Black	Black	3.2	Medium	39	Rare fossils	.....
Lower Production	8	270	1′	Black	Drab	...	Medium	10	.....	.....
	9	292	1′	Brown	Drab	3.4	Tough	18.5	.....	.....
	10	296	4′	Buff	Drab	...	Tough	33	.....	Cracks like mud when powder is dried; chert concretions
	11	300	5′	Buff	Drab	3.4	Medium	23	.....	Clayey, carbonaceous
	12	317	3′	Black	Black	2.9	Crumbly	60	.....	Brecciated
	13	348	2′	Light	Greenish	3.5	Tough	34	.....	Compact
	14	373	3′	Light	Black	...	Tough	13	.....	Shaly, fine bedded
	15	418	1′ 6″	Brown	Brown	...	Soft	64	.....	.....
	16	425	1′	Brown	Brown	...	Soft	22	Fossiliferous	.....
	17	435	1′	Brown	(Solid piece of sandy shale passing with no visible line of demarkation into limestone with pronounced effervescence)					
	18	553	22″	Dark	Brown	Tough		20	Small brachiopods numerous. Immediately below the limestone, with no clay or shale intervening, occurs the 4′ 5″ coal bed (No. 1) underlain by light shale	

Carboniferous system known as the Pennsylvanian, inasmuch as it was first studied and best exemplified in Pennsylvania. The drill passed through the top series (the Upper Productive), the middle series (the Lower Productive) and sank about 25 feet into the bottom series (the Mansfield). To differentiate between these series is difficult, since they merge into each other insensibly. But somewhere the line of demarkation is passed.

Eight beds of coal (ten different layers) were encountered. The top one (9 inches thick), No. 8 of the old geological survey, is only 151 feet from the surface. The bottom one, No. 1 (4 feet 5 inches thick), is 555 feet from the surface. All of the beds together aggregate 23 feet and 3 inches.

I examined every foot of the core for limestone and found eighteen different layers, varying from 6 inches to 5 feet in thickness and giving a total of only 46 feet of limestone in the 600 feet of strata penetrated. This is a small amount.

At eighteen places the cores showed limestones by effervescence in cold dilute hydrochloric acid. These sections were numbered, beginning at the top, and samples taken. The beds vary from 6 inches to 5 feet in thickness. There is great disparity between the amount of intervening strata. In some cases a stratum of limestone of one character follows immediately below one of another character. Again, these are far apart. For example, between beds No. 7 and No. 8 are 110 feet of shales with no intervening limestone and between No. 17 and No. 18 even a greater amount, 117 feet, of shale and sandstones, totally devoid of limestone. Below No. 7 the Upper Productive may be said to end, and below No. 18 the Lower Productive ends. The Mansfield sandstones and conglomerates begin about 40 feet below the lowest coal. The distance between the beds are as follows: 0, 10, 9, 3, 71, 10, 110, 21, 3, 0, 12, 27, 23, 40, 5, 9, 24, 117 feet.

The colors are usually grey with light bluish spots, rusty, brown, and black. The streak varies from white through dark buff to black. All are of light specific gravity and in hardness vary from 3 to 3.5. Beds Nos. 1 to 4, No. 9, and Nos. 13 and 14 are tough. The others are friable or fissile, like soft shale.

One hundred milligrams of each of the eighteen were dissolved in cold hydrochloric acid and after 12 hours the residues were weighed. No. 1 was the most completely dissolved. The residue weighed but ½ of a milligram. No. 15 proved to be the least soluble, 64 per cent remaining in the test tube. Beginning with

the most soluble and ending with the least soluble, the arrangement is as follows: No. 1 (residue .5 mg.), No. 3 (residue 4.4 mg.), No. 4 (residue 4.5 mg.), No. 8 (residue 10 mg.), No. 2 (residue 11 mg.), No. 14 (residue 13 mg.), No. 6 (residue 17.5 mg.), No. 9 (residue 18.5 mg.), No. 18 (residue 20 mg.), No. 16 (residue 22 mg.), No. 11 (residue 23 mg.), No. 10 (residue 33 mg.), No. 13 (residue 34 mg.), No. 7 (residue 39 mg.), No. 5 (residue 40 mg.), No. 12 (residue 60 mg.), No. 17 (residue 64 mg.).

At a depth of 440 feet a 4-foot bed of a tough white, hard rock, called limestone in the drill record,[1] is encountered. In cold hydrochloric acid it is almost insoluble, leaving a residue of 80 per cent. It is a siliceous dolomite.

It is interesting to note that bed No. 18, very rich in small brachiopods, lies *immediately above* Coal No. 1 at a depth of 453 feet. In the drill record this is called Dark Shale. To find a limestone roof without intervening shale or clay is an unusual occurrence.

[1] Report on the Progress and Condition of the Illinois State Museum of Natural History for the years 1909 and 1910, p. 32.

Biological Papers

SOME NOTES ON THE FORESTS OF OGLE COUNTY.

W. L. EIKENBERRY.

The principal rocks of Ogle County are the loose and porous St. Peter's sandstone, limited to the vicinity of Rock River, and the Trenton and Galena limestones. The latter formations underlie most of the county and are covered with a thin layer of Illinoian and Iowan drift, which is rarely so much as twenty feet thick.

It is shown by Leverett that before the Glacial Epoch the channel of Rock River lay in the eastern part of the county, but at the retreat of the ice it adopted a new course, such as to occasion a rearrangement of most of the drainage channels of the county. The insignificant Mud Creek appears to be about the only preglacial stream in the county. Kyte River occupies its ancient valley in part, but with direction of flow reversed. Under these circumstances it will be understood that the topography adjacent to the river is very new and immature. In general, the region near the river and other important watercourses consists of a gently rolling upland trenched by narrow and deep ravines.

The soil is the alternation of loam and clay common to glaciated regions, together with some limestone residual soil and the sand along the river arising from the disintegration of the sandstone. The most marked contrast is between the rich black soil of the gently rolling prairies remote from the river and the humus-poor clays of the rapidly eroding area nearer to the streams.

Consideration is here given principally to that part of the county lying west of Rock River and south of Mud Creek, including the basins of Mud Creek, Pine Creek, and adjacent parts of the valley of the river.

PLANT SOCIETIES.

Any consideration of the prairie societies is excluded by the scope of this paper. There may be distinguished four forest associations: (1) Oak, (2) Maple, (3) Pine, (4) a characteristic Bottom Association. Only the first and fourth are of general occurrence. In the absence of suitable physiographic situations, swamp forests are wholly wanting from the part of the region under consideration.

1. Oak Association.

The oak association is the characteristic one of the country—

it everywhere gives character to the woodland. The list of trees occurring in it with sufficient frequency to be considered a part of the general formation includes the following: *Quercus velutina, Q. coccinea, Q. alba, Q. macrocarpa, Q. rubra, Q. Muhlenbergii, Carya ovata, Prunus serotina.* If one may venture an opinion from the fragmentary data now available, the following would appear to be the original distribution of the species mentioned.

(a) A group of relatively xerophytic species occupied the rapidly eroding lands and formed a zone of considerable width on the prairie side of all forested areas. The Black and Burr Oaks and the Shellbark Hickory are most prominent. Wherever the original line of contact between the prairie and the forest can yet be found, the Burr Oaks make up the outer fringe, and where cutting has exposed the Black Oaks to the sweep of drying westerly winds they are usually dying.

(b) A more mesaphytic group (*Q. alba, Q. rubra, P. serotina*) occupied most of the forested region not yet deeply eroded, showing a tendency to occur also in the more protected central part of large forests, the margins of which were occupied by Black and Burr Oaks.

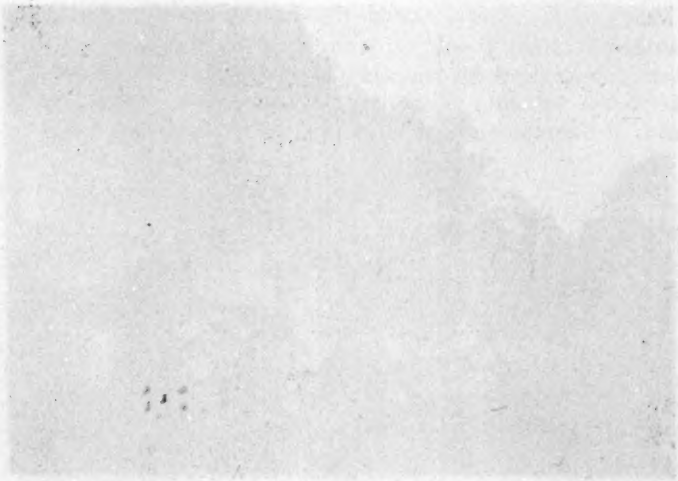
2. Maple Association.

So far as the present conditions of the timberland show, the maple formation is restricted to an area of less than a square mile near the head of Mud Creek and a similar area reported from Kyte River. The latter I have not been able to visit. It will be recalled that, according to Leverett, the valleys of both streams are preglacial, and in this particular the situation differs from that of most other forest areas in the county.

This association is doubtless to be correlated with the Beech-Maple formation of other localities. The most plentiful species are *Acer sacharum, Ulmus americana,* and *Fraxinus americana. Ostrya virginiana* is almost as common as the preceding, and there are many large trees of *Quercus alba* and *Q. rubra. Tilia americana,* both species of *Juglans* and a few specimens of *Prunus serotina* make up the remainder of the forest. Beech is of course wholly absent. Abundant seedlings of basswood, elm, ash, *Ostrya* and maple promise a continuation of the same type of forest if properly protected. The oaks and the wild cherry, mostly mature trees, are doubtless to be interpreted as relics of a former condition not yet wholly past.

Figure 1. Grove of White Pine on Pine Creek near C. B. & Q. railway bridge.

Figure 2. Bluff overhanging Pine Creek. *Acer, Tilia, Ostrya, Taxus, Cornus.*



It can hardly be doubted that this formation is a pioneer rather than a relic, and therefore an expression of the climate of the region. In the course of nature it would doubtless have become the dominant type in much of the region.

3. Pinus strobus.

The most unusual feature of the plant geography of Ogle County is the occurrence within its limits of a grove of unmixed White Pine. This species contributes a very picturesque feature to the scenery of Pine Creek but is not numerically important, with this single exception. On the eastern side of the cañon-like valley of the creek immediately south of the C., B. & Q. Railway the bluffs are occupied by a fine growth of pine which is so dense as to exclude every other tree and shrub. The grove covers about twenty acres. Adjoining it, on the same side of the creek, is a rectangular timber lot of about 160 acres, much of which is not pastured. This growth consists almost wholly of white oak, though there are a few scattered cherries and pines. The undergrowth is unusually heavy, including, besides the young oaks, *Cornus*, etc., which is common in such places, also a really surprising growth of young pines of all sizes. In many places they are literally coming up like grass.

It is evident that if the pines are here a disappearing type, it cannot be because the factors of soil and climate are unfavorable to them, and one feels in looking at the sturdy growth of young pines that they stand about as good a chance as the young oaks of conquering the region. It is the testimony of old residents that this grove did not exist in early days but that it has been produced naturally since the settlement of the country. It is said to be less than seventy years old, and this is corroborated by the age of the trees and other biological evidence.

So far as the writer is informed, this is the only stand of the species in the State. Associated as it is with scenery of great natural beauty, it is to be hoped that some way will be found to preserve this unique feature from destruction.

4. Bottom Associations.

The bottom associations are such as are familiar everywhere. I shall merely remark that they show no points of special interest excepting that the scarcity of sycamore, hackberry and cork elm indicates that this may be near the northern limit of these species in the valley of Rock River.

THE LIMESTONE CLIFFS.

There are certain peculiarities in the zonation of the vegetation on the limestone cliffs which must be mentioned, since the same phenomena seem not to have been noted in descriptions of similar regions. The Galena formation on Pine Creek furnishes the best examples.

The course of Pine Creek is entrenched in a generally horizontal upland. Vertical cliffs of considerable height are common. On the upland above one of these cliffs is commonly found the usual oak forest, and this approaches to within a few rods of the cliff. At about the point at which the surface begins to round downward to meet the vertical face below, the trees are replaced by a very xerophytic grass and shrub zone of which a characteristic member is *Physocarpus*. Below the *Physocarpus* zone, and immediately above the vertical face of the cliff, where the slope is so steep that only a few handfuls of soil are able to find lodgment in the crevices, is an assemblage of mesophytic plants. The most characteristic forms are *Tilia, Ostrya, Acer saccharum, Taxus canadensis* and *Cornus stolonifera*. *Pinus* and *Juniperus* may also be present. *Taxus* is practically restricted to this sort of habitat. *Tilia, Ostrya* and *Acer* occur together here as on the talus slopes and in the climax forest. *Ulmus* may also be found. Beneath this zone there is the bare vertical rock face bearing only the usual very limited vegetation.

There are no experimental data upon which to base an explanation of the occurrence of a mesophytic society at the top of a cliff, but general observation leads to the following suggestion. The water table must fall as it approaches the cliff, but owing to the heavy bedded character of the underlying rocks, it does not fall rapidly. The much larger number of horizontal channels than vertical ones leads the percolating waters in an almost horizontal direction. The water table therefore falls far enough below the surface near the edge of the hill to make its shoulder rather xerophytic, but intersects the steeper lower slope near the top of the vertical face. The steepest slope is therefore the dampest and the vertical face may in wet weather become a dripping cliff. The argument is strengthened by the independence of this plant formation of all accidents of exposure, or any other factor of the sort and its persistent recurrence upon every cliff of this description, large or small. Its complete correlation with this peculiar physiographic situation would indicate that its explanation is to be found within the substratum.

The sandstone cliffs on Rock River are quite in contrast. These cliffs are porous. On their tops stunted pine, cedar and black oak are almost alone. Basswood, maple, hop hornbeam and yew are *never present*, and the growth is never dense.

COMPETITION AND GENERAL RELATIONSHIPS AMONG THE SUBTERRANEAN ORGANS OF MARSH PLANTS.

EARL E. SHERFF.

The statements and conclusions in the present paper are based mainly upon my work at Skokie Marsh, in the years 1910 and 1911.[1] The marsh itself is closely associated with Skokie Stream, a small, intermittent, meandering stream that begins west of Waukegan, Illinois, and ends west of Glencoe, Illinois. Its vegetation may be described briefly as consisting of reed-swamp, swamp-meadow and true meadow.

Darwin, in his Origin of Species, pointed out that because two species of the same genus usually resemble each other, the struggle between them, if they come into competition, will generally be more severe than between two species of different genera. Clements has since emphasized the fact that similarity in growth form rather than in systematic position determines the intensity with which different species compete. One of the main objects in my investigation at Skokie Marsh was to ascertain how far similarity in growth form among different species (particularly in regard to depth of subterranean organs) results in competition; or, conversely, how far dissimilarity in growth form results in ability to live together harmoniously in a complementary relationship.

We have here [illustrated on screen] a view of the rhizome interrelationships of the bur-reed (*Sparganium eurycarpum*), the arrow-leaf (*Sagittaria latifolia*) and one of the water knot-weeds (*Polygonum Muhlenbergii*), where the three species occur together in the less hydrophytic parts of the reed-swamp. . . . As shown on the screen, the knot-weed rhizomes and roots lie rather deep. . . . It will be seen that the roots of the arrow-

[1] A general and also more elaborate account than here possible will be found in the Botanical Gazette, 53: 415-435, 1912.

leaf pass downward several inches below the surface and consequently compete with the roots of both the bur-reed and the knotweed for water, oxygen, etc. The soil being rich usually in at least water and nitrogenous materials, the root competition is probably not serious. But before passing on we should note the complementary relationship between the rhizomes of the arrow-leaf and those of the bur-reed. At first it might seem that since the rhizomes of both species start growth at the same level—near the surface—they would come to be more or less in each other's way. But usually at the very outset the arrow-leaf rhizomes grow downward for several inches, then take a horizontal direction for some distance, and finally point upward again. At the distal end is produced a stem-tuber and from this arises a new plant the following season. Thus the arrow-leaf may establish new plants at advantageous distances from the parent plant and yet, in doing so, avoid mechanical obstructions to a great extent. To determine exactly how far this freedom from mechanical obstruction promotes the vegetative increase of arrow-leaf plants would demand, of course, accurate experimental investigation in a quantitative way. Some able botanists, notably Clements, are inclined against the consideration of mechanical obstruction as a factor in competition; they insist upon the importance of "physical" (i. e., physiological) factors. And while in the main their contentions are well founded, it cannot be denied that pronounced exceptions do exist. For example, at Skokie Marsh, a study of the water-lily association in the reed-swamp showed that where the arrow-leaf was present its rhizomes had been intercepted in great numbers by the large, semi-decayed rhizomes of the water-lily (*Nymphaea advena*). And, in the majority of such cases, the propagative stem-tubers of the arrow-leaf had decayed. Even in the encasing soil, many instances were found where the stem-tubers had been mechanically impeded and had mostly decayed. And here, while the decay must have been due to some one or more physiological causes, yet these causes could not have operated had not mechanical impediments first retarded the stem-tubers for a sufficient length of time.

As our knowledge of the interrelationships of subterranean organs progresses in the future, we shall probably find that often, in the case of certain species with large subterranean parts, there is offered or received mechanical resistance which is immediately decisive in competition because of the physiological processes that it promotes.

Our last picture is that of a community containing chiefly the blue flag (*Iris versicolor*) and the blue violet (*Viola cucullata*). Their rhizomes are short and thick, lie just below or at the soil surface, and form a dense mat. Nevertheless, when one or more square feet of this mat were carefully removed and the soil in the interstices among the rhizomes was taken away, it was estimated that the interstices, as viewed from above, constituted from 35 to 60 per cent of the total. Evidently, then, so far as mere room was concerned, several other species could have grown —in fact, did grow—in these interstices. But they were plants which rooted higher or lower; or, if at the same level, they were species not largely dependent upon rhizomes or stolons for multiplication. Thus, where the blue flag had reached a maximum of frequency, the water knot-weed, with a low root system, and the bedstraw (*Galium Claytoni*), with a high root system, might live; but the sweet flag (*Acorus calamus*), with rhizomes similar to those of the blue-flag and lying at a similar depth, and dependent largely on rhizomes for multiplication, was absent.

A detailed presentation of the conclusions growing out of my work is impossible here. But in closing I would point out the importance of exhaustive study, in the future, of the interrelationships among subterranean organs, especially since these have much to do with the compactness of vegetative growth in an association. For, induced directly or indirectly by the conditions following such compactness, have doubtless arisen many of the most important adaptations in the growth forms of various species.

THE RANGE OF EVAPORATION AND SOIL MOISTURE IN THE OAK-HICKORY FOREST ASSOCIATION OF ILLINOIS.

WADE M'NUTT AND GEO. D. FULLER.

I. EVAPORATION.

The oak-hickory forest, an association characterized by the presence of the white oak (*Quercus alba*), the red oak (*Q. rubra*) and the shag-bark hickory (*Carya ovata*) as its dominant tree members, occupies a unique position in Illinois, appearing as the climax association of much of the woodlands bordering upon the

prairie region and as the association next below the climax in areas farther removed from the grasslands where the beech-maple forest association forms the climax. The composition and relationships of these associations have been fully discussed by Cowles,[1] Whitford[2] and others, but almost nothing has been known quantitatively of the physical factors (other than rainfall) that determine their character and extent. Some preliminary studies upon the evaporating power of the air in some of the associations involved have already been reported to this Academy,[3] but the oak-hickory forest was not included among the associations studied. To supply this deficiency, the evaporating power of the air and the soil moisture have been determined during the season extending from April 22 to October 28, 1911, in a fairly undisturbed forest situated upon the Valparaiso moraine, about twenty miles southwest of Chicago, near the little village of Palos Park.

In the evaporation determinations the porous cup atmometer was employed and the directions given by its inventor, Livingston,[4] for its operation were so closely followed that any extended account of its management becomes quite unnecessary. All instruments were standardized before being set up and the standardization repeated at intervals of six to eight weeks. By the coefficients thus obtained all readings were reduced to a common unit. Readings were made weekly throughout the season and the results expressed as the average daily rate of loss for the interval between the readings. These results have been graphically represented with the weekly intervals as abscissae, and the amount of daily loss by the standard atmometer, in cubic centimeters, as ordinates.

Four stations were established, three upon the upland and one in a small depression, a wedge-shaped flood-plain of a small stream, usually without water during the summer. The upland stations were upon the low sloping hills of the moraine about twelve meters above the level of Lake Michigan, where the soil was of a fine texture, being composed of boulder clay with a small admixture of sand. In the depression there was a mixture of alluvium and humus, no clay appearing at a depth of 30 cm.

[1] Cowles, H. C. The physiographic ecology of Chicago and vicinity. Bot. Gaz., *31*: 73-108, 145-182, 1901.
[2] Whitford, H. N. The genetic development of the forests of northern Michigan. Bot. Gaz., *31*: 289-325, 1901.
[3] Fuller, Geo. D. Evaporation and plant succession. Trans. Ill. Acad. Sci., *4*: 119-125, 1911, and Bot. Gaz. *52*: 193-208, 1911.
[4] Livingston, B. E. Operation of the porous-cup atmometer. Plant World, *13*: 111-119, 1910.

The stations were numbered arbitrarily, number one being located in the depression, numbers two and three in the ungrazed forest, and number four in a portion of the forest which had been grazed. The forest is here largely composed of white oak (*Quercus alba*) and red oak (*Q. rubra*), with occasional trees of the bur oak (*Q. macrocarpa*), shag-bark hickory (*Carya ovata*) and the bitternut hickory (*C. cordiformis*). Station four was almost devoid of undergrowth, but at stations two and three there were seedlings of the trees, particularly of the white oak, together with a considerable amount of the hazel (*Corylus americana*) and a few other shrubs. The instruments were placed in spots with an average amount of shelter from both the trees and the shrubs. The forest about station one had, in addition to the species already enumerated, trees and seedlings of the white ash (*Fraxinus americana*) and of black walnut (*Juglans nigra.*)

An examination of the evaporation records shows that the evaporating power of the air was highest during the month of

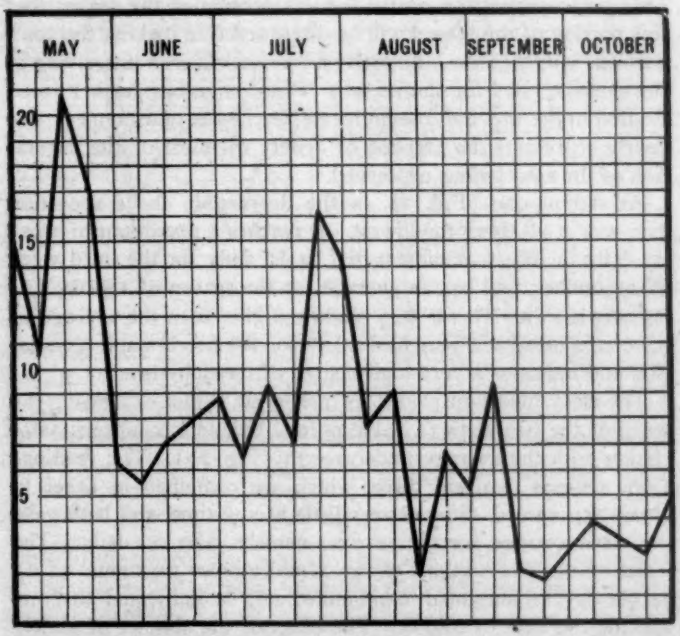


Figure 1. Graph representing the evaporating power of the air in a depression in the oak-hickory forest.

May. Doubtless this may be explained by the unusual conditions that obtained during this month. It had the highest temperature record experienced since the establishment of the Chicago Weather Bureau in 1871. The average temperature for the month was 10 degrees above the normal; for six days it reached or exceeded 90° F., and it reached 94° on the 25th, 26th and 27th of the month. The percentage of sunshine, 79 per cent, was also greater than that observed during any previous May. In contrast, during September, the period with least evaporating power, the temperature was about normal, while the relative humidity was somewhat above and the percentage of sunshine considerably below the normal mean. All these meteorological factors influence the evaporating power of the air profoundly, and their great variation gives emphasis to the necessity of records extending over more than one season before definite conclusions may be reached with safety.

The unusual conditions during May, combined with the absence of foliage during a portion of the month, gives such an excessively high evaporation record for this portion of the season that this portion of the record will be disregarded in making the comparisons which follow, although they are considered in arriving at the average rates for the season. This course has further justification in the fact that the high rate reached at midsummer more nearly represents the extreme of aridity for most of the vegetation of the associations concerned.

At station one (Fig. 1), in the depression, the evaporation rate was at all times the lowest. It reaches a maximum of 16.21 cc. daily in July, a minimum of 1.74 cc. daily for the third week of September, and has an average for the season of 189 days of 8.3 cc. per day. This is very slightly higher than the average of 8.1 cc. reported last year by Fuller[8] for the beech-maple association and indicates a very high degree of mesophytism.

The most important record for the forest is that expressing the mean of the two stations in the normal upland oak-hickory association with the average undergrowth (Fig. 2b). The readings from stations two and three, which are combined in order to obtain this record, differed very little at any time, and both gave the same average for the season—namely, 9.89 cc. daily. The mean of the two stations shows a midsummer maximum of 17 cc. per day, an autumnal minimum of 2.87 cc. daily, and an average for 189 days of 9.89 cc. The effect of the absence of undergrowth is plainly shown by the record (Fig. 2a), exhibiting the

highest rate of the series, having a midsummer maximum of 22.12 cc. per day, and a daily average of 12.74 cc. The minimum, 2.77 cc. per day, almost exactly coincides with that of the ungrazed forest, 2.87 cc. daily. A comparison of the two graphs (Fig. 2) will show that the least divergence in the evaporation

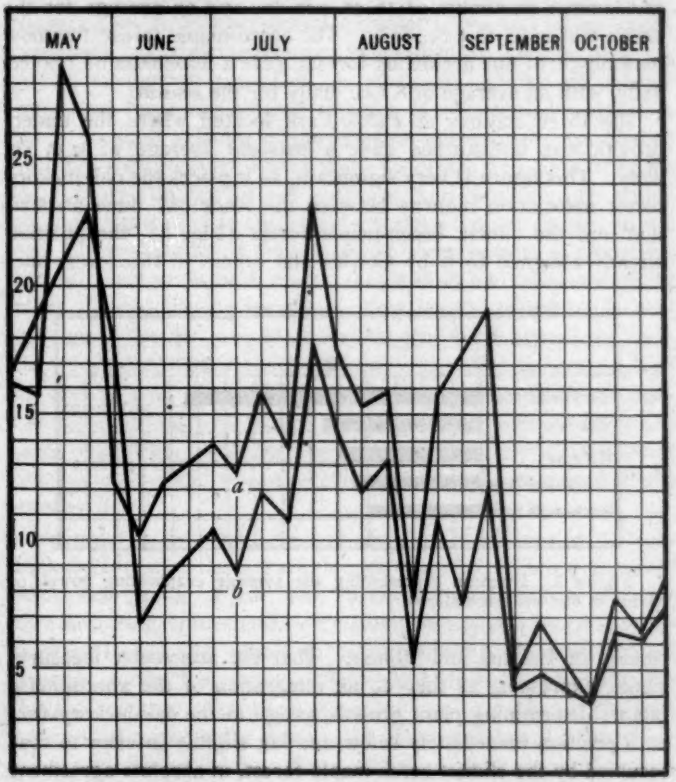


Figure 2. Graphs representing the range of the evaporating power of the air in (a) the grazed and (b) in the undisturbed portion of the oak-hickory forest.

rates of the grazed and ungrazed portions of the forest occurred in the spring and autumn, when the trees were in a more or less leafless condition.

A comparison of these records with those obtained by Fuller,[8] in 1910, in related forest associations is most interesting and

instructive. The pine dune association with a maximum of 17.5 cc. per day and a daily average of 11.3 cc. for the season compares closely with the record of the grazed oak-hickory forest, with an average of 12.74 cc. daily for the season. The oak dune forest he studied, which has been regarded as less mesophytic than the one at Palos Park, gave similar evaporation rates with midsummer maximum of 16 cc. per day and an average for the entire season of 10.3 cc. daily. The beech-maple forest, the most mesophytic of our deciduous forests, gave a maximum of 12.0 cc. daily, with an average of 8.1 cc. daily for the season.

The three stations at Palos Park located where the undergrowth was undisturbed gave a seasonal average of 9.35 cc. daily. This figure is very significant, as it places the oak-hickory forest association midway between the black oak dune association and the climax beech-maple forest (Fig. 3), the position already assigned to it by Cowles and others in the forest succession of Indiana and Illinois. That the atmometer measurements, expressing as they do an integration of the atmospheric factors determining plant growth, assign to the oak-hickory forest a position immediately below and but slightly inferior to that occupied by the climax beech-maple forest, in absolute agreement with the conclusion already reached by a consideration of other data, must be regarded as of the greatest importance.

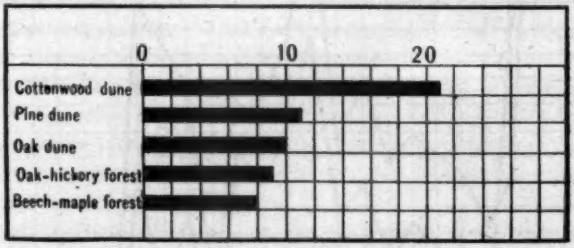


Figure 3. Diagram representing the average evaporating power of the air in various associations.

Expressing the same result upon a percentage basis, with the average rate throughout the season of 1910 in the beech-maple forest as a unit,[3] the comparative evaporating power of the air in the oak-hickory forest is 115 per cent; in the oak dune association, 127 per cent; in the pine dune association, 140 per cent; and in the cottonwood dune association 260 per cent.

II. SOIL MOISTURE.

While ecologists have usually been agreed that the water of the soil is the most important single factor limiting the development of vegetation, very few quantitative determinations of this factor have been made. This has been due largely to the difficulty in obtaining a standard by which the water content could be related to plant growth. The percentage of water in one soil which would produce a luxuriant vegetation, in another of different texture, would not support any plant life whatever. Livingston[5] recognized that the water-holding capacity of soils varied and had a fairly constant relation to the relative soil moisture conditions, but only with the very recent work of Briggs and Shantz[6] has a satisfactory function of soil moisture been recognized by which to relate vegetation to the actual amount of water present in the soil. They determined the amount of water present in a particular soil when permanent wilting occurred in Kubanka wheat, the plant adopted for the standard. This amount expressed in percentage of the dry weight of the soil they have termed the *wilting coefficient*, and it represents the water content above which all growth must occur; life, however, is maintained for very considerable periods with much less water. The same workers also gave data which show that many ordinary mesophytic plants vary very little in their wilting coefficients from the standard wheat employed.

In order to determine the soil moisture conditions in the oak-hickory forest at Palos Park, weekly samples, each consisting of about 300 grams of soil, were taken at atmometer stations one, two and four, from depths of 7.5 cm. and 25 cm. below the surface. The soil was placed in tightly closed wide-mouthed jars, brought to the laboratory, weighed and dried at a temperature of 100° to 104° C. until it ceased to lose in weight. The percentage of water to the dry weight of the soil was thus obtained. Using the same soils, the wilting coefficients were obtained according to the wax seal method described by Briggs and Shantz (loc. cit.). Graphs representing the range of soil moisture have been plotted with weekly intervals as abscissae, while the ordinates represent the percentage of the soil moisture present. The wilting coefficients are represented upon the same diagrams in broken

[5] Livingston, B. E. Relation of soil moisture to desert vegetation. Bot. Gaz., *50*: 241-256, 1910.

[6] Briggs, L. J., and Shantz, H. L. The wilting coefficient for different plants and its indirect determination. U. S. Dept. of Agr., Bur. of Plant Industry, Bull. No. 230, 1912.

lines; hence the amount of water available for the purposes of growth is shown by the interval between the graphs representing the soil moisture and the line representing the wilting coefficient.

The wilting coefficient will be found to vary considerably in the different locations dependent largely upon the amount of humus present in the soil. Thus, in the depression, it is seen to be 18.9 at 7.5 cm. (Fig. 4B) below the surface, but only 12.5 at 25 cm. (Fig. 4D), due to more humus in the surface layers. The abundance of the water supply in this locality is seen by the very

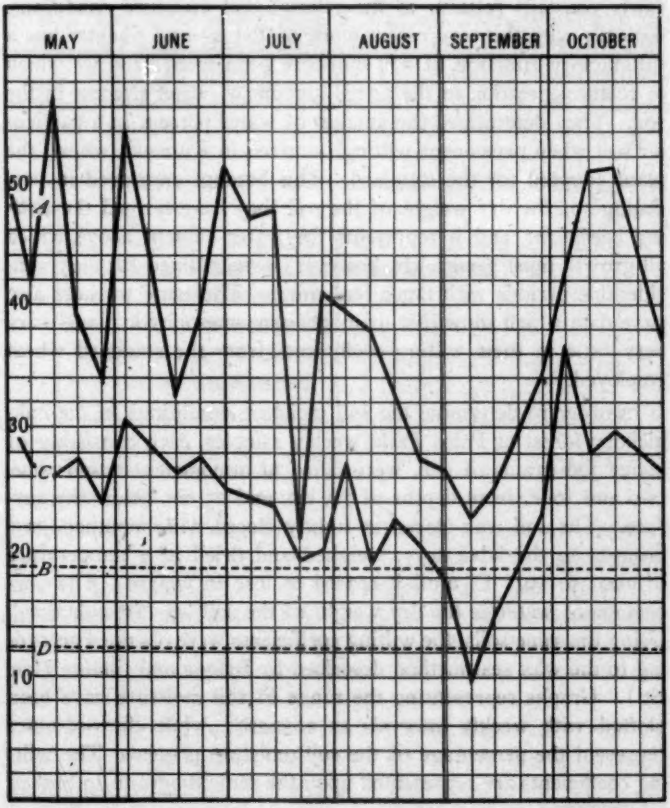


Figure 4. Graphs representing the range of soil moisture throughout the growing season, at 7.5 cm. (A) and at 25 cm. (C), below the surface, in the depression in the oak-hickory forest, and the wilting coefficients (B, D) at these depths.

large percentage in May, June and October, and the plentiful and constant supply during the critical weeks of midsummer. Only once does the supply fall below the wilting point—namely, during September, at the 25 cm. level (Fig. 4). The mesophytism of the soil may possibly best be expressed by noting the average amount by which the actual water content exceeds the wilting coefficient during the critical ten weeks beginning with July 1st. At the 7.5 cm. level there will be found to be an average of 18.3 per cent, and at 25 cm. 7.8 per cent of the dry weight of the soil in water available for growth during these midsummer weeks.

At station three, the smaller amount of humus present in the

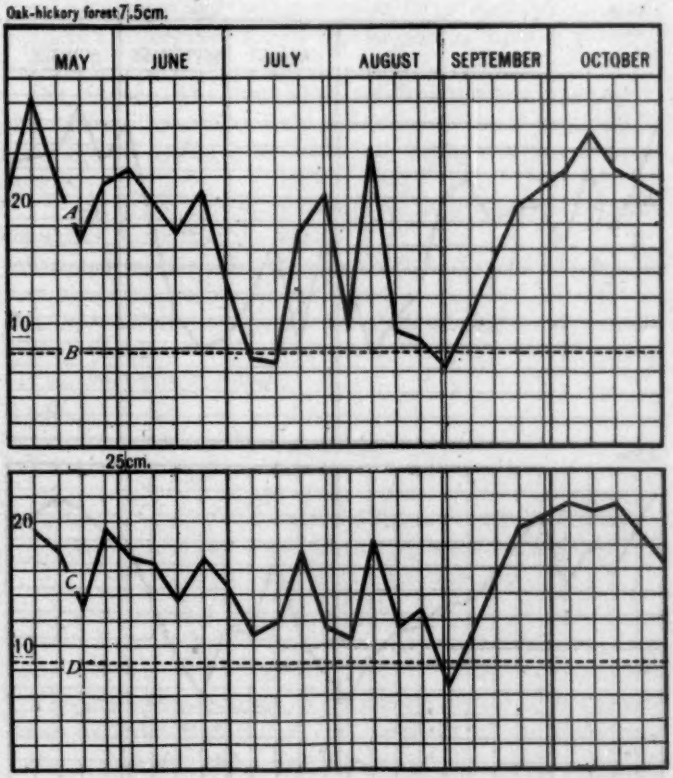


Figure 5. Graphs representing the range of soil moisture at 7.5 cm. (A) and at 25 cm. (C) below the surface in the oak-hickory forest, and the wilting coefficients (B, D) at these depths.

soil is indicated by the smaller wilting coefficients, 7.7 and 8.5 per cent (Fig. 5). The amount of water available for growth is also less, and once at 25 cm. and twice at 7.5 cm. it fails. The greater fluctuation in the supply at the higher level is very evident at this station (Fig. 5A), but is also apparent in the other localities (Figs. 4A and 6A). Here the surplus supply for the ten weeks from July 1st averages 4.6 per cent at 7.5 cm. and 4.1 per cent at 25 cm.

The soil records at the grazed station are noticeable for their great range, and for the deficiency in the supply at the 7.5 cm. level (Fig. 6). Here during the ten critical weeks of midsummer

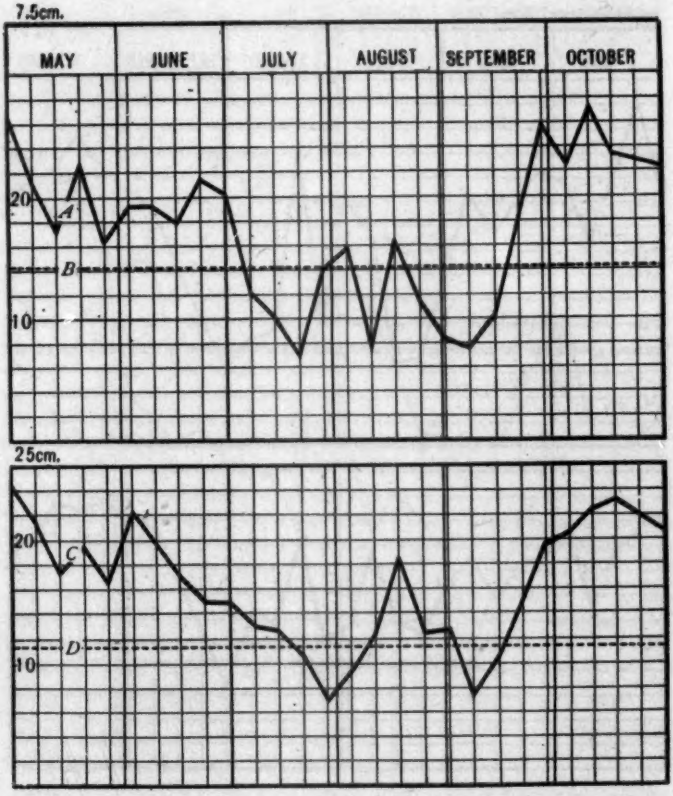


Figure 6. Graphs representing the range of soil moisture at 7.5 cm. (A) and at 25 cm. (C) below the surface, in the grazed oak-hickory forest, and the wilting coefficient (B, D) at these depths.

there is, instead of a surplus, a deficiency in the water supply amounting to an average of 3 per cent at the 7.5 cm. and 0.5 per cent at 25 cm.

The writers gratefully acknowledge their indebtedness to Miss Laura Gano for making the atmometer readings and soil moisture determinations during July and August.

SUMMARY.

The evaporating power of the air in the lowest stratum of the oak-hickory forest, as determined for the growing season of 1911, places the association midway between the black oak dune forest association and the beech-maple forest association, a position which exactly corresponds with its place in formerly observed succession.

The data on soil moisture show that the water-retaining powers and wilting coefficients of the soils studied varied considerably and appeared largely to be determined by the amount of humus present.

The soil of the depression showed the most favorable moisture conditions throughout the season.

The soil moisture determinations afford too meager data to permit any but the most tentative conclusions, but it is believed that they will tend to confirm the position assigned to the oak-hickory forest association upon the basis of its evaporation rate.

The University of Chicago.

GERMINATION AND GROWTH OF THE COTTONWOOD UPON THE SAND DUNES OF LAKE MICHIGAN NEAR CHICAGO.

GEORGE D. FULLER.

EXTENT OF THE ASSOCIATION.

The first tree association to become established upon the sand dunes of Lake Michigan is one composed of the cottonwood *Populus deltoides* and a few shrubs, among which species of *Salix* and *Cornus* are conspicuous. Occasionally *Populus deltoides* is replaced by *P. balsamifera;* its ecological equivalent. The detailed examination of the composition and extent of this

association has been so well made by Cowles[1] that little could be added to his account. To summarize: it is characterized by the one tree species only and extends from immediately within the fore-dune to the region where the dunes become established, comprising the greater part of the moving dune-complex and forming a zone from 100 to 300 meters wide. In the dune region comparatively few cottonwoods are found beyond these limits, mingling with the members of other associations.

It is the purpose of this paper to discuss briefly two of the physical ecological factors of the association which have been quantitatively studied, viz.: the evaporating power of the air,[2] and the range of soil moisture during the growing season,[3] and to attempt to relate the germination and growth habits of the principal tree member of the association to these factors.

EVAPORATING POWER OF THE AIR.

This factor has been measured by means of the Livingston atmometer during the past two growing seasons, and some of the results for the summer of 1910 have been reported to this Academy.[2] The readings of the atmometers were taken weekly and corrected by the application of the coefficients necessary to express the results in term of loss from the standard instrument adopted by Livingston. When these results are plotted as graphs having the weekly intervals as abscissae and the loss per day in cubic centimeters as ordinates (Fig. 1), they show that the evaporating power of the air in the lower stratum of the association is excessive and subject to extreme variations, indicating that the demands for water made upon the aerial parts of the vegetation are very great. The average rate for the season of 1910 was 21.1 cc. per day and that for 1911 amounted to 24.6 cc. per day. A further comparison of the conditions existing during these two years may be obtained by a study of these two graphs, representing as they do the mean of the observations taken at three stations from May 1 to October 31 of these years. The graphs will be seen to be similar in character, the differences being traceable to differences in atmospheric conditions peculiar to each particular year, and they demonstrate that the evaporation conditions are rigorous and indicate a xerophytic response. The amount of xerophytism may be indicated by a comparison with the evaporation occurring

[1] Cowles, H. C. The ecological relations of the vegetation of the sand dunes of Lake Michigan. Bot. Gaz., *27*: 95-117, 1899.
[2] Fuller, G. D. Evaporation and plant succession. Trans. Ill. Acad. Sci. *4*: 119-125, 1911.

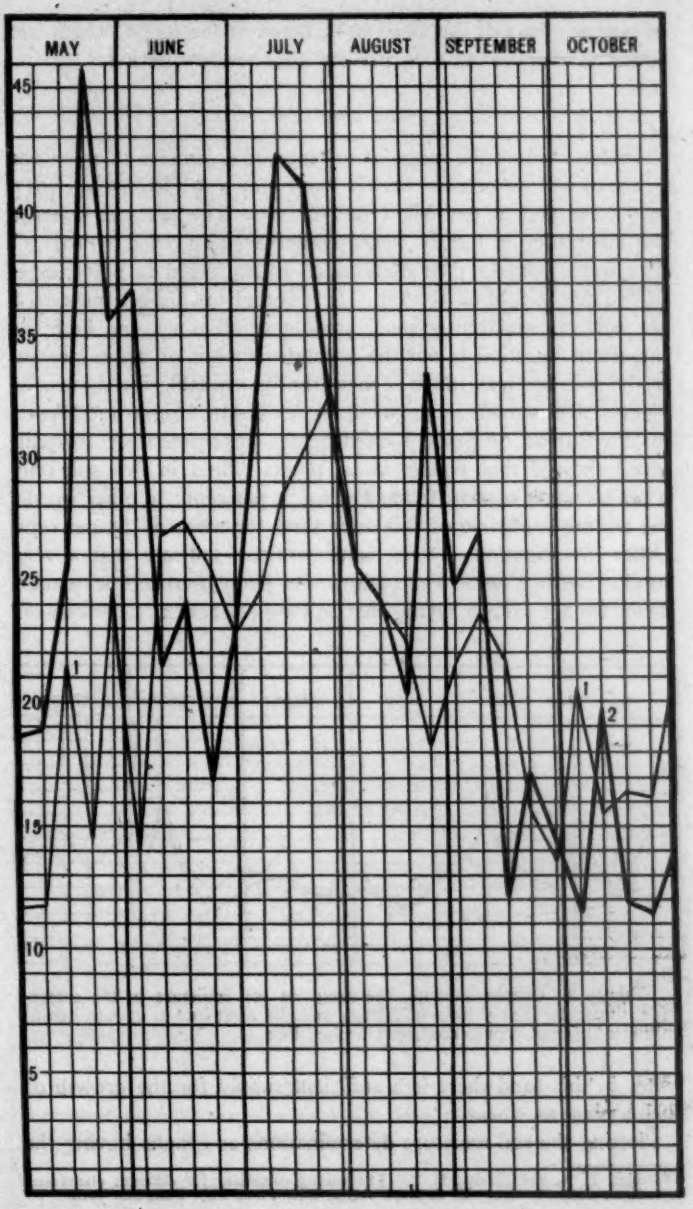


Figure 1. Graphs illustrating evaporating power of the air during 1910 and 1911.

in similar strata of the mesophytic beech-maple forest, which was found to average but 8 cc. per day for the same period.

SOIL MOISTURE.

In determining the range of soil moisture, samples of about 200 grms. of soil were taken weekly from May 1 to October 31, 1911, at 7.5 cm. and 25 cm. below the surface. The soil was taken to the laboratory in tightly closed containers and dried at 104° C. The water content thus determined is expressed in percentages of the dry weight of the soil. It is found to range from 2 to 8 per cent, an apparently small amount at all times, but here the important question is not the absolute amount of water present in the soil, but how much is there that is available for the use of plants? Tests made by the methods devised by Briggs and Shantz of the Bureau of Soils, United States Department of Agriculture,[3] showed that young wheat plants wilted in this soil only when its water content fell as low as .75 per cent; in other words, the *wilting coefficient* of this dune sand for wheat is .75 per cent. Other investigations by the same workers indicate that a very similar *wilting coefficient* obtains for many herbaceous plants; hence we are safe in saying that so long as there is 1 per cent of

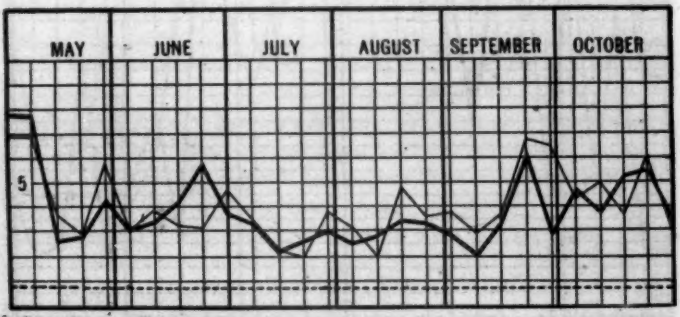


Figure 2. Graphs showing the range of soil moisture in the cottonwood dune; the heavy lines at 7.5 cm. and the light line at 25 cm. depth; wilting coefficient represented by a broken line.

water in this sand there is a sufficient supply for the growth of such a plant as wheat.

Plotting the soil moisture determinations as graphs having the

[3] Briggs, L. J., and Shantz, H. L. The wilting coefficient for different plants and its indirect determination. U. S. Dept. Agric. Bur. Plant Ind., Bull. 230: 1912.

Figure 3. Cottonwood with roots uncovered by removal of sand. Young trees developing from the exposed roots.

Figure 4. Dune moving into Calumet river. Cottonwood seedlings persisting although sand is encroaching upon them. The buried branches rooting and becoming independent trees.

weekly intervals between the collections as abscissae and the percentage of water present in the soil as ordinates (Fig. 2), it will be seen that the moisture present in the soil is at all times more than double the wilting coefficient. The interval between the curve representing the soil moisture and the line representing the wilting coefficient represents the amount of water available for growth, and has been termed *growth water*.[4] It will be apparent that there is always a supply of growth water, although it must be admitted that the amount available in July could permit no very heavy draughts, still the soil conditions must be regarded as by no means very arid,—so mesophytic, indeed, do they appear, viewed from the point of water supply, that one would be quite at a loss to account for the very sparse vegetation upon any such basis. A cause for the xerophytism may be found in the instability of the substratum, a factor fully discussed elsewhere by Cowles and others.

VEGETATIVE PRODUCTION.

It has been previously stated that the cottonwood dune association is one almost entirely dependent upon vegetative reproduction for its maintenance. As the sand advances over the trunk and branches of these trees, adventitious roots are given off, and what was originally one tree becomes a group of several (Fig. 4), each with its own root system. Doubtless the constancy of the soil moisture supply is closely related to this condition of vegetative reproduction. A vegetation dependent upon such a method of reproduction will, however, increase in amount very slowly, especially as the very instability which multiplies the trees by burying them afterwards destroys them by removing the sand, exposing the roots, and finally leading to their overthrow (Fig. 3). In this uncovering process there is also a limited amount of vegetative reproduction from adventitious buds which arise upon the exposed roots at a distance from the parent plant (Fig. 3). When the amount of erosion by the wind is limited and soon checked, such adventitious shoots may result in the production of a considerable number of new trees grouped about the parent, but such reproduction is again to be regarded as limited in extent and of minor importance. These two methods, however, do account for the permanency of the tree upon the unstable substratum of the moving dune complex, although they

[4] Fuller, G. D. Soil moisture in the cottonwood dune association of Lake Michigan. Bot. Gaz., *53*: 512-514, 1912.

do not explain the establishment of the species. For this establishment we must find the seedlings, and none exist upon the moving dune complex.

REPRODUCTION BY SEED.

In the experience of the writer, cottonwood seedlings are to be found in the dune region in two situations, and in two only. In the recession of the waters of Lake Michigan, many shallow ponds and lagoons were cut off from the main body of water and not a few still persist, more or less filled by the action of the moving sand and vegetation. Their damp margins are often sprinkled with cottonwood seedlings (Fig. 4); some of these survive and surmount the advancing sand and thus account for the presence of these trees at any considerable distance from the lake.

The second seed-bed is to be found where the wind has swept out the sand to a depth approaching the level of the waters of the lake; here the soil surface and the top of the water table almost coincide in depressions termed by European ecologists *pannes*. Such pannes are (Fig. 5) often found immediately behind the fore-dune within 25 to 100 meters of the shore. These depressions are flooded at high water in the spring and even at midsummer the almost saturated sand is quite stable and seems admirably suited to the production of cottonwood seedlings, for here they are found in abundance. As they increase in size they collect sand, the panne being transformed into an ever-increasing dune (Fig. 6), which soon begins to move inland. With the growth of the dune and its subsequent advance many of the young trees are killed, but some survive and, surmounting the advancing sand, form the only tree vegetation of the active dune complex.

CONCLUSIONS.

1. The evaporating power of the air in the exposed cottonwood dune association is great in amount and variable in degree, indicating rigorous atmospheric conditions.

2. The soil moisture is never less than twice the wilting coefficient of the soil; i. e., there is always a supply of water available for plant growth.

3. Vegetative reproduction maintains the stand of cottonwoods upon the dunes through the ability of the species to send

Figure 5. Panne with cottonwood seedlings.

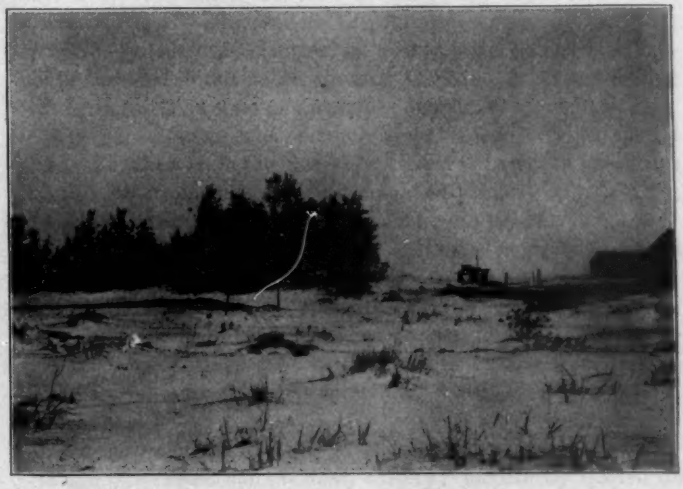


Figure 6. A small dune formed about young cottonwoods developed in a panne.

out adventitious roots as the trunk and branches are buried and to produce adventitious shoots from the roots as they are exposed.

4. The seedlings apparently require a large amount of moisture for their development, for they are found only along the margins of ponds and streams, and in the pannes; hence the establishment of the cottonwood is antecedent to the dunes upon which it is able to maintain itself.

The University of Chicago.

RECENT ADDITIONS TO THE CATALOG OF ILLINOIS MOLLUSCA.

FRANK COLLINS BAKER.

In 1906[1] the writer published a preliminary list of the Mollusca known to live in Illinois. Since that time a number of species new to the local fauna and new to science have been discovered. These are briefly recorded in the following pages. There are certain nomenclatorial changes, as well as other data, which cannot be included in this paper, for lack of space. A revised catalog will be in order as soon as time and opportunity is available.

Page 76.—*Margaritana margar tifera,* Linné. This species should be taken from the list. The record is based on specimens mixed with *monodonta,* which is found in Illinois.

Page 86.—For *Corneocyclas*[2] *peralata,* read *peralta.*

Page 86.—Add the following: *Pisidium neglectum,* Sterki Illinois (Sterki). *Pisidium neglectum corpulentum,* Sterki. Lilycash Creek, near Joliet, Will county (Ferriss; Handwerk).

Page 89.—*Vivipara subpurpurea texana,* Tryon. This reference is to be omitted. The specimen did not come from Illinois.

Page 93.—*Amnicola limosa pallida,* Hald, is a synonym of *limosa.*

Add the following:

Page 93.—*Amnicola sheldoni,* Pilsbry; incorrectly quoted on page 95 as *Pomatiopsis sheldoni. Amnicola missouriensis,* Pilsbry. Canton, Fulton county (Walker).

Page 99.—*Physa ancillaria warreniana,* Lea. Lake Forest, Lake county, Lake Michigan (Woodruff).

[1] Bull. Ill. State Lab., N. H., VII, Art. VI, Sept., 1906.
[2] The name *Pisidium* is now generally accepted, and *Corneocyclas* cannot stand.

Page 100.—*Physa gyrina oleocea,* Tryon, is the young of *Physa gyrina.*

Add the following:

Page 102.—*Ancylus hinkleyi,* Walker. Golconda, Pope county; Elizabethtown, Hardin county (Hinkley).

Add the following:

Page 103.—*Lymnaea*[3] *columnella casta,* Lea. Mercer county (Marsh).

Page 103.—*Lymnaea obrussa plica,* Lea, should read *L. obrussa exigua,* Lea.

Page 103.—*Lymnaea obrussa modicella* should read *L. humilis modicella.*

Page 104.—*Lymnaea sterkii* should read *L. parva sterkii.*

Page 104.—*Lymnaea humilis* should read *L. humilis modicella.*

Page 104.—Add: *Lymnaea humilis rustica,* Lea. Joliet, Will county (Ferriss).

Page 104.—*Lymnaea catascopium pinguis* is a synonym of *catascopium.*

Page 105.—*Lymnaea caperata umbilicata* is a synonym of *caperata.* The true *umbilicata* has not yet been found in Illinois.

Page 105.—*Lymnaea palustris michiganensis,* Walker, is the immature form of *Lymnaea elodes,* Say. Lake Villa, Cedar Lake, Lake county; Bowmanville, Cook county (Baker); Joliet, Will county (Ferriss); sloughs of Winnebago county (Hinkley); Wolf Lake, near Chicago; North Branch of Chicago River, Chicago (Jensen); Mason county (Nason); Quiver Creek, Mason county (State Laboratory); Bristol, Kendall county (Walcott); Havana, Mason county (Walker); Northwest and Calumet Lake, in ditches, Cook county; creek near Bangs Lake, Waukonda, Lake county (Woodruff).

Page 106.—*Lymnaea reflexa jolietensis* should read *Lymnaea elodes jolietensis,* Baker. Additional records: Berry Lake, Cook county (Higley); south of Wolf Lake, Cook county (Jensen).

Page 105.—*Lymnaea exilis,* Lea.

Page 106.—*Lymnaea Kirtlandiana,* Lea. Mud Lake, Grand Crossing, Chicago, Cook county (Baker); Berry Lake, Cook county (Higley); Crystal Lake, McHenry county (Nason).

Page 106.—*Lymnaea reflexa iowaensis,* Baker, and *Lymnaea reflexa crystalensis,* Baker, are immature forms of *reflexa.*

Page 105.—*Lymnaea pallida,* Adams, is to be taken from the

[3] See the writer's monograph, Special Bulletin 3, The Chicago Academy of Sciences.

list, as it does not inhabit Illinois. The references quoted should be placed under *obrussa*.

Page 111.—Add: *Bifidaria clappi*, Sterki. Ottawa, La Salle county (Calkins).

Page 113.—Add: *Succinea ovalis optima*, Pilsbry. Fox River (Calkins); Carpenterville, Kane county (Calkins); Rock River, Oregon, Ogle county (Baker). *Succinea ovalis totteniana*, Lea, is a synonym of *Succinea ovalis*, Say.

The Succineas are badly in need of revision, and some of the names given on pages 113 and 114 are to be retained provisionally, pending a revision of the whole genus.

Page 114.—For *Polygyra tridentata juxtigens*, read *Polygyra tridentata juxtidens*.

Page 115.—For *Polygyra profunda alba*, Witter, read *Polygyra profunda alba*, Walker. *Polygyra sayii*, Binney, should be changed to *Polygyra sayana*, Pilsbry (name preoccupied).

Page 116.—*Polygyra exoleta*, Binney, should be changed to *Polygyra zaleta*, Binney (earlier name).

Page 117.—*Polygyra monodon fraterna*, Say, should be changed to *Polygyra fraterna*, Say.

Page 119.—Add: *Vitrea* (*Paravitrea*) *significans* (Bland). Augerville Woods, Urbana, Champaign county (Zetek).

EARTHWORMS FROM ILLINOIS.

FRANK SMITH.

The literature on Illinois earthworms has been very scanty. In 1888, Garman, of the State Laboratory of Natural History, described *Diplocardia communis* as a new genus and species from specimens of earthworms found at Urbana. He also listed three species of *Lumbricidae* from the vicinity, all well-known European forms.

In 1893, Ude, of Hanover, Germany, described a form collected at Danville, Illinois, as a new genus and species, *Geodrilus singularis*, but it is now considered merely as a variety of Garman's *Diplocardia communis*.

In 1895 I had the opportunity to describe another species of *Diplocardia* from Havana, Illinois, and also a species of aquatic earthworm from the same place, belonging to the genus *Spar-*

ganophilus. These are the only papers that have dealt with new species of earthworms based on Illinois material. A paper by me in 1900, dealing chiefly with other *Oligochaeta,* contained a list of eleven species of earthworms known in the State. At present my list includes three species and three varieties of *Diplocardia,* of which two varieties are undescribed; one species of *Sparganophilus,* and seven species and one variety of *Lumbricidae,* with three other forms not yet determined—a total of eighteen different forms.

It may be of interest to know something of the source and general relationships of the different types represented in the Illinois fauna. At the present time there are more than one thousand recognized species of earthworms in various parts of the world. The great majority of these have been made known within the last twenty years, chiefly through the efforts of five Europeans, and one Swede, Eisen, who for a number of years lived in San Francisco and worked on West and Central American species.

These worms are grouped into four great families, of which one is limited to Ceylon and southern India, and need not receive attention. The other three are represented in Illinois. The great family *Megascolecidae* includes more than half of the known species, and is found chiefly in the tropical regions and the Southern Hemisphere. The most primitive type is the genus *Eodrilus,* which is represented by species in India, South America, Africa and Australia, a distribution typical of the survivors of ancient groups of other types of animal life. They date back at least as far as the Triassic in the early Mesozoic.

According to Michaelsen, a prominent investigator in this field, *Diplocardia* was one of the first branches to develop from the *Eodrilus* trunk, and probably appeared in Mexico or Central America during the Jurassic in time for derivatives from it to invade Africa by way of the land connection formerly existing between Brazil and the African continent. *Diplocardia* itself seems to have spread to the north instead of southward, and species are known from Mexico, Lower California, Texas, Florida, Nebraska and Illinois. Its representatives are among the dominant forms of our endemic species.

The *Geoscolecidae* constitute another great family of the earthworm group, and seem to have developed at least as early as the Jurassic in the northern continental area. Some went southward through Europe into Africa, where many species now exist, while a still greater development took place on the American con-

tinent. One of the oldest genera was *Sparganophilus*, in the Jurassic, which seems to have remained behind in North America, while other American representatives went south, not much before the Eocene, to Central and South America, where they have differentiated widely and into numerous genera and species. *Sparganophilus* species are known from Mexico, California, Florida, Illinois and the Great Lake region, and form a second group of prominent endemic species. Probably the only reason why the list of States is not longer is simply that no one has collected and identified the worms from other States. It seems a little odd that the genus *Sparganophilus* should have been founded by an Englishman on specimens taken from the Thames, but there seems excellent reason for believing that his conjecture was correct, viz.: that their occurrence there was accidental, due to the introduction of a purely American form, perhaps with aquatic vegetation. He was not able to find the species in later years, and I think there is no record of any other occurrence of the genus in the Old World.

The third and last earthworm family to receive attention is the *Lumbricidae*. These are the most recent forms to appear, and seem to have been derived from the *Glossoscolecidae*, probably in Southwest Asia, where there is a great variety of endemic forms. They probably invaded Europe in the Eocene and North America in the Oligocene. There are numerous endemic forms in Europe and but few in the United States. These latter are found chiefly in the Southeastern Atlantic coast region. None are yet positively known to occur in Illinois. Notwithstanding the lack of endemic lumbricid species in Illinois, it is probable that 90 to 95 per cent of all the specimens that would be taken in random collections made in any of the settled districts of Illinois or of the United States would be included in a few species common also in Europe, and more than 50 per cent would belong to a single species, *Helodrilus caliginosa*. These species are found the world over where Europeans have settled and cultivated the soil. They abound about the towns of Africa, South America and Australia and crowd out the native species as they seem to do here.

The habits and mode of life of the earthworms are such that they must necessarily be destroyed in any region subject to general glacial action, and there can be no doubt that the earthworm fauna of the glacial territories of Eurasia and North America have been occupied by invaders from the territory further south

since the retreat of the glacial ice mass. The conditions found in the earthworm fauna of Europe are interesting in this connection. In the various parts of Southern Europe are found dozens of endemic species, while Northern Europe is occupied exclusively, with a single possible exception, by forms also found further south. The line separating the northern territory with peregrine forms from the southern region with endemic forms is found to correspond quite closely to the southern border of the ice sheet at its most southern extension during the glacial period. This would seem to indicate that the time since the glacial period has been too brief for the differentiation of endemic forms from the southern invaders. Our knowledge of the earthworm fauna of North America is altogether too imperfect to permit a statement as to corresponding conditions here.

It is my wish to gain a more extended knowledge of the distribution of earthworms in this State, and particularly of the endemic forms. We know nothing of the northern limits of the range of *Diplocardia*, and nothing of the earthworm fauna of the unglaciated area of Southern Illinois. If any of the members of the Academy will aid in the securing of material which will throw light on the two topics suggested, I shall be very glad to secure it and return named material in exchange.

Science in Secondary Schools

REPORT OF THE COMMITTEE APPOINTED TO INVESTIGATE THE RELATIONS OF THE PURE AND APPLIED SCIENCES IN HIGH SCHOOLS.

WORALLO WHITNEY.

That there may be no confusion with respect to the purpose of the committee, I shall quote from the resolution adopted at the last meeting of the Academy, in which the appointment of the committee was requested. I quote the following:

"Inasmuch as the demand for industrialism in education has become widespread and is causing the addition of many new courses in applied science to the curriculum of the high schools and the readjustment of the established courses in pure science; and,

"In view of the fact that there is little data at the command of educators which might enable them to reorganize the work in science on correct lines without risk of serious mistakes fraught with danger of disaster to both the pure and applied sciences,

"Your committee recommends that the Academy appoint a committee of five members to investigate the practice of secondary schools in:—

1. The organization of the applied sciences.
2. The correlation of the pure and applied sciences.
3. The adjustment in the pure sciences to meet local conditions and satisfy the demand for practical courses."

After considerable study to find the best method of attacking the work, the committee decided that it could be accomplished best by a division of the investigation and assigning part to each member of the committee. The following subtopics were decided upon:

1. The effect of the demand for applied science upon the pure sciences in ordinary high schools where no courses in the applied sciences are given. 2. The relations of the pure and applied sciences in schools where both are taught. 3. The relation of these sciences in authorized agricultural high schools. 4. Their relations as shown by analysis of text-books of agriculture. 5. The preparation of teachers for the science work of high schools.

Unfortunately for our scheme of work, two of the members of the committee found that they were unable to do their work. To remedy this, the fifth topic just read was dropped for the present,

and the second is included in my report, since the first and second topics are closely related.

I shall retain our original division of the topics in my discussion and consider first the effect of the demand for industrialism in education upon the courses in pure science in the ordinary high schools. The demand comes under various guises, such as "practical courses," "vocational courses" and "applied courses." Within the last two or three years great pressure has been brought to bear upon teachers of the pure sciences to modify these courses and make them more "practical," as it is usually put. How this pressure has been met, is the question which I have set myself to answer in so far as the scope and means of such an investigation as this can determine.

It seemed best to begin by studying the situation in Chicago, since I am well acquainted with the history of science teaching in this city from the time of the inauguration of modern laboratory methods, and since also the evolution of science teaching in Chicago is undoubtedly similar to its evolution elsewhere, except that it is slower because of the larger bodies of people to move.

There has been a slow evolution in methods of teaching the various departments of science from the very beginning of the establishment of the laboratory. The present agitation has only served to accelerate somewhat a movement already in progress. At first there was insistence upon strict scientific methods—such as the inductive process of observation and inference. A textbook open in the laboratory was strictly forbidden. The study of types with the emphasis on morphology was insisted upon. The order of study was always evolutionary. Even the laboratory tables were copied from the style found in college laboratories. In fact, the entire course was modeled on the college course—simply a slightly modified edition of the college course. The tendency has been away from this hand-me-down college work toward something specifically adapted to high school needs, —a high school course in science suited to the experience, ability and needs of the high school pupils. I think I can illustrate just what this progress has been by taking one of the high school sciences and comparing a former course used in Chicago with one recently adopted. For this I shall take botany, since in most or all of the other sciences, whether or not the experiences of the home and daily life are utilized, is a matter of laboratory practice in the application of the topics of study, while in botany the topics themselves give a hint as to the method used. In physics,

for example, the topics electricity, heat, light, etc., will appear in all courses, no matter what the treatment, and only a study of the methods in use in applying the topics will show what progress has been made.

For the purpose of this inquiry it will be sufficient to compare two courses of study for botany—one dated June, 1908, and in official use since that time, the other recently adopted for future guidance.

A comparative study of these two outlines shows that in the earlier one the year's work was divided into two parts corresponding to the semesters, one occupied with a survey of the plant kingdom taking up the groups in evolutionary order, the other, usually given in the second semester, dealing with the seed plants and outlined in structural order. Theoretically this looks like an ideal plan, and it appealed to college men who write text books of botany for us and to teachers of botany fresh from the university, as the only course to give. But we who are in the business of teaching botany in high schools had difficulties in applying it. Our pupils were not interested, little enthusiasm could be aroused—many pupils failed—in fact, only the brightest pupils got anything out of the first semester's work. The second semester's work was needed to restore interest lost in the first half year's work, and even that dealt with structure to such an extent that the interesting spots in the course were in danger of being lost sight of. The work on the local flora in the spring was the only thing that saved our classes in botany from extinction. We turned out few botanists.

As soon as the average teacher realized what was happening, he began to inject into the course various features, mostly in the line of field and home studies, to add interest and appeal to the experience of the pupil. The most popular of these were studies of fall flowers, leaves, trees, woods, and various studies of the commercial uses of plants and plant parts.

Turning now to our recently adopted course, it is easy to see how this has finally worked out. It will be noted at once that the studies of plant groups occupy only about half of a semester, instead of an entire semester. Evidently, detailed studies of structure must be omitted in using this course, since there will not be time for such work. The title itself is quite illuminating, indicating that the laboratory is not the only place to study botany. It is interesting to note various topics not found in the old course, all of which appeal to the human interest of the pupil, such as

*COURSE IN BOTANY.
(In effect Sept., 1908.)

1. A laboratory course, following the authorized manual, including *first-hand* notes and drawings.

No. lab. periods.	Branch or Topic.	Type—careful study.	Comparative study.	Experiments and observations in physiology.
8	Algæ.	Pleurococcus. Spirogyra.	Vaucheria. Fucus.	Osmosis. Photosynthesis. Response of cell contents to alcohol, iodine and salt solution. Necessity of soil salts.
8	Fungi.	Yeast. Mucor.	Microsphæra. Mushroom.	Conditions for growth. Need of food.
1	Lichens.	Lichen.		
7	Bryophytes.	Marchantia. A moss. (Complete life history.)		Power of revival after drying.
12	Pteridophytes.	A fern (both generations).	Equisetum. Lycopod.	Grow fern spores.
4 8 12	Gymnosperms. Monocotyls. Dicotyls.	Pine. Lily.	Some other monocotyl. A crowfoot; A rose; a legume; A violet; a figwort; A composite.	Osmosis in seeds; in root hairs; in root (carrot exp.). Photosynthesis, need of light; need of carbon-dioxide; product. Circulation.
10	Seeds and seedlings.	Squash. Bean. Corn.	Five other seeds collected by the pupil.	Seed germination, conditions of as to light, water, heat, air and external plant food. Place of growth in seedlings, root and stem. Respiration.
5	Roots.	Oat. Bean. Carrot.	Anacharis roots. Clover roots.	Response to stimulus. Root pressure. Food storage.
8	Stems.	Cottonwood. Ash.	Grape; trillium; Wild cucumber; Potato; onion.	Water content, soil, green wood, herbs, fruits.
12	Leaves.	Geranium.	Solomon's seal. Clover; ash.	Transpiration, rate and amount. Wilting and restoration. Use of protective coverings.

* Condensed from official bulletin of Board of Education.

BOTANY.

LABORATORY AND FIELD COURSE. 1b. (First Semester.)
(In use Sept., 1912.)

Topics.	Suggested Subtopics.
Fall flowers	Principal types of common wild and garden flowers, especially the compositæ. Insect pollination.
Leaves	Work of leaves. Light relation of leaves. Identification of trees by their leaves.
Weeds	Types of weeds and their characteristics. The struggle for possession. Collection of common weeds.
Seeds and fruits	Types of seeds and fruits; methods of distribution. Collecting seeds; planting tree seeds.
Preparation of plants for winter	Trees, perennials, biennials and annuals considered in this relation. Bulb culture.
Forestry	Identification of trees in winter conditions. Planting and caring for trees; forestry. Enemies of trees.
Algæ	The cell; plasmolysis. Types of algæ showing development of plant body. Types of reproduction; establishing home aquaria.
Fungi	Life history of a fungus. Types of fungi from an economic standpoint. Bacteria.
Liverwort, moss, fern, pine	Evolution of the plant body. Spore reproduction; the seed.
1a. (Second Semester.)	
Seeds and seedlings	Germination; the seedling. Respiration; response to stimuli. Seed testing; food storage; uses to man.
Roots	Types, modifications. Food storage; uses of roots to man. Functions of roots; soils and fertilizers.
Stems	Types, structure and modification. Work of stems; uses to man. Woods; identification and collection.
Leaves	Structure, modifications. Work of leaves; economic uses.
Gardening, window and outdoor	Planting rules, planning garden and homeyard. Garden accessories, hot beds, cold frames, etc. Types of garden plants; propagation of plants, cuttings, grafts, offsets, etc.
The flower	Structure and function by means of a typical flower.
Local flora	Types of flowers, flower families. Wild flower collection, flower calendar. Use of keys; how to make an herbarium.

fall flowers, preparation of plants for winter, forestry, gardening, local flora, etc.

Another very interesting and significant feature is the comparative flexibility of the two courses. In the old course the amount of time to be given to each subject is stated in hours. No such statement is to be found in the new course. The types in the old course are all stated positively, while in the new course the heading reads "suggested subtopics." Again, in the statement accompanying the new course, the teacher is given entire liberty with respect to the order in which the topics shall be taken up. The first course is arbitrary and inelastic. The new course is flexible and easily adjusted to any teacher's special needs.

The trend has been away from a strictly scientific development of botany which did not recognize the pupil and his interests to a flexible course, where the purely scientific development of the subject has been subordinated to the development of the pupil's interest in botany. The scientific aspects are not lost by any means, but they are not the sole thing now.

I have given a good deal of time to the study of the development of botanical teaching in Chicago, because it seems to be typical of the trend in all the pure sciences. It will therefore not be necessary to give much time to a consideration of the other sciences. Zoölogy has experienced like changes in method indicated by the use of the insects as an introductory study and by the dropping of the echinoderms from the course. This last was not done without a struggle, for the impulse to take up the groups one after another, omitting none, is very strongly rooted in the minds of zoölogy teachers.

In physics there is consistent effort to make application of the laws and principles of the science to problems of everyday life. In chemistry, analysis of food adulterants and other articles used in the home give the needed relation of the subject to the pupil's experience.

It would not do to assume that conditions in Chicago necessarily resemble those in other places. I, therefore, undertook an investigation to ascertain how the pure sciences are being taught in various other parts of the country. Manifestly, this could not be done by examination of courses of study, and so I prepared a brief questionaire which I sent to representative schools in Illinois and other States of the middle West, and a few to the extreme West. The returns were fairly satisfactory, considering that it required the combined reports of teachers of four departments.

For botany and zoölogy the following questions were asked: 1. State in order as given by you the topics and groups of plants (animals) taken up during the year and the time allowed for each. 2. Upon what do you place most emphasis? 3. What, and how much, outdoor work do you do with your classes? For physics and chemistry there were two questions: 1. State in order as given by you the topics taken up during the year. 2. Do you do any so-called "practical work" with your classes? If so, what?

A tabular resumé of the reports on these courses of study has been prepared and is appended to this paper. While the number of reports is not great, the schools included in the report represent a wide variety and are representative schools, so that it is probably safe to assume that their courses represent the prevailing tendencies. Wide variations are shown, especially in botany, but on the whole certain things stand out clearly, marking what we may call the attempt to relate the teaching of the sciences to the experience of the pupil.

In botany, as has been indicated, there is wide divergence, but it can readily be seen that the tendency is away from the evolutionary type method. It is also quite evident that there is as yet no settled conviction as to what should take its place. In zoölogy the insects are universally chosen for beginning the work and receive the greater share of the time. There is not much indication that the mammals are receiving a fair share of attention. If economic importance and nearness to everyday experience are to be controlling motives, then one would expect to see more time given to studies of mammals. The reports show on the whole considerably greater uniformity of practice than with botany.

The reports upon physics and chemistry did not give much of value on the first question so far as concerns this paper, and no tabulation of this portion has been made. The reports on the second question show almost unanimous agreement in giving the experiments a practical bearing and, and in the case of chemistry, in introducing many experiments with substances used in the home. Questions were sent out for physiography, but the reports did not seem to have much bearing on the question under discussion and have not been tabulated. It is fair to say for those making reports that it was found necessary to condense the reports as much as possible for use in the tables. Some of the reports were quite extensive and deserving of publication in their complete form if space had permitted.

Considering the reports as a whole, it will be seen that there is a decided tendency toward emphasizing the aspects of each subject that come within the experience of the pupils in everyday life. In some cases it seems to have been carried to excess, notably with tree studies in some courses in botany, and possibly in some of the courses in chemistry. The important principles of each subject should never be lost sight of, no matter what course is given, and I judge that there is danger of this in some cases. The movement, however, seems to be a healthy one on the whole and for the good of science insofar as it appeals to a greater interest on the part of pupils and their parents. That it is a progressive movement, in which some schools have made much greater progress than others, is also evident, and what we should expect and wish for.

I shall now take up my second topic, namely, the relation of the pure and applied sciences in high schools where both are taught. There are practically only two applied sciences which have been incorporated in high school curricula to such an extent

OUTLINES OF COURSES OF STUDY IN BOTANY.

Place.	Time sem.	Course.	Emphasis placed upon.	Field work.
Menominee, Wis.	2	Leaves, flowers, fruits, seeds, stems, 8 weeks; corn plant, oat plant, potato plant, 3 weeks; bacteria, 2 weeks; algæ and fungi, 6 weeks; liverworts, mosses, ferns, 3 weeks; spring flowers, about 12 weeks.	Corn, bacteria, fungi, spring flowers.	About 4 trips.
Minneapolis, Minn.	2	As in Coulter's text book of botany. Higher plants, 6½ months; fungi and bacteria, 1 month; algæ, mosses, liverworts, ferns, 6 weeks.	Trees, weeds, economic factors.	One lesson each week during spring and fall.
Detroit, Mich.	2	First semester,life history of angiosperm, plant,—seeds, seedlings, roots, stems, leaves, flowers, fruits, a few common families. Second semester,—life history of typical forms of algæ, fungi, moss, ferns. Preparation of herbarium. Study of stem structure and woods.	Development of power to observe, think and correlate facts of plant life, relation of plants to surroundings.	Study habits of plants—identification of native and shade trees.
Aurora, Neb.	1	1. Seed, roots, stem, leaves, fruit, flower. 2. Physiology of the above. 3. A brief view of ecology. 4. Economic importance of plants. 5. A brief study of cryptogams.	The structure and physiology of common flowering plants found in our neighborhood.	One excursion.
Quincy, Ill.	2	1. Plant relations. An introduction to forest trees, collecting, drawing, and mounting woods, foliage, leaves and seeds. 2. Plant structure. Collecting, drawing and mounting 25 flowering plants.	Ecology.	One period each week (2 hrs.).
Saginaw, Mich.	2	Leaves 10 weeks, stems 6, roots 4, seeds 4, germination 2, the cell 1, algæ 2, fungi 2, mosses 2, ferns 2, flowers and fruits 5.	Structure and functions, classification trees and shrubs, cultivated plants, alternation of generation.	Fall and spring, 20 periods in yards and parks.
Kansas City, Mo.	2	Flowering plants 4 weeks, algæ 4, fungi 6, bryophtes 1, pteridophytes 1, spermatophytes 8, plant processes 4, plants of economic importance, products, etc., 12 weeks.	Evolution and economic importance.	Several trips during fall and spring. Assigned individual work.
Crookston, Minn.	2	Anatomy and physiology of plants 13 weeks, ecology 8 weeks, cryptogams with emphasis on parasitic fungi 7 weeks, classification and preparation of herbarium 4 weeks, reviews 4 weeks.	Ecology, economic importance, work of plants, recognition of common plants.	Excursions for identification of weeds and other plants, collecting trips.

Monmouth, Ill.	2	Leaves, stems, roots—germination of seeds, 35 periods. The groups algæ to gymnosperms 29, angiosperms (general) 9, flowers and insects, seed dispersal 5, monocotyls 5, dicotyls 12, plant breeding, forestry, plant associations 4 periods, collect and mount 20 wild flowers, analyze 15.	Structure and adaptation in field and laboratory studies, economic importance.	Group work under teacher's direction. Collecting specimens.
Lansing, Mich.	1	Entire time given to flowering plants, 3 weeks on analysis flowering plants. Aim to make nature lovers of pupils, not scientists.	Plant as an individual in a certain relation to its environment.	Study of a selected tree throughout season. Collecting specimens. Volunteer work.
Indianapolis, Ind. Shortridge H. S.	2	Identification of trees, forestry studies as field work. Algæ 6 weeks, fungi 5, liverworts, mosses, ferns 6, pine 1, seeds and germination 4, roots 2, stems, 3, buds 2, leaves 2, flowers 5 weeks. Much practical work in gardening, forestry, fruit culture, flower calendar, etc.	Economic applications. Acquaintance with common plants.	Five required trips, others optional. Collecting tree leaves, 30 required, making flower calendar of 40 to 260 plants.
Ottawa, Ill. Township H. S.	2	Thallopytes about half semester, bryophytes and pteridophytes rest of semester. Spermatophytes spring semester. Some ecological work is given and lasts 8 to 10 weeks, given to determination of species of plants 3 hours per week.	Evolution of plant life and physiology of plants.	Ecological work and identification of plants.
Kewanee, Ill.	1	Four groups, mophological study 7 weeks, physiology of angiosperm types 6 weeks, ecology of region and some agricultural problems 5 weeks.	Physiology and ecology.	Very little. Classes too large.
Cedar Rapids, Iowa.	2	1. Field and laboratory study of weeds, seed dispersal, identification of 30 common weeds. Relation of flowers and fruits. Germination studies. Life relations, structure, physiology and ecology of roots, stems, leaves. Soil studies—Plant growing room provides specimens at all times. 2. Winter condition of buds, field study of trees. Plant groups. Plant families of locality. Pollination studies, plant breeding.	That phase of the work with which the pupils are most vitally concerned in their out-of-school life. For example, plant propagation, bulbs, grafting, condition of fruit buds in spring, etc.	Eight to ten excursions to fields during class hours. Much assigned individual work on special topics during entire year, often requiring daily outdoor studies.
Ft. Wayne, Ind.	2	1. Seed plants,—morphology, physiology and ecology of seeds, leaves, bud, stem, flower, fruit. Plant societies, classification, economic value of main groups. 2. Life histories,—algæ, fungi, mosses, ferns, club mosses, gymnosperms, angiosperms.	Morphology, evolution of plants, economic value.	Assigned work, pupils gather laboratory materials.

Place.	sem. Time	Course.	Emphasis placed upon.	Field work.
Ottumwa, Iowa.		1. Seed plants, leaves, 10 weeks (4 weeks to identification of trees by means of leaves), roots 2 weeks, stems 3 weeks, seeds 3 weeks. 2. Algæ, fungi, liverworts, mosses, ferns, flowers; identification of flowering plants.	Recognition of common trees, life process, food tests, etc.	Study trees. Pupils collect twigs of 50 trees. Ecological studies made. Assigned work.
Sycamore, Ill.	1	Seeds and their foods 5 weeks, roots 2, stems 4, leaves and light relations 3, algæ 1, mosses and ferns 2, weeds and struggle for existence 1, plant breeding 1.	The plant as a whole and as a part of the organic world.	Special topics assigned. Four excursions to study tree forms, light relations and plant distribution.
Paris, Ill.	1	Angiosperms 11 weeks, pteridophytes 3, fungi and algæ 2, gymnosperms 2.	Conditions of economic importance as soil, seeds, parasites, struggle for existence.	Individual field work—classes too large for class excursions.
Pontiac, Ill.	1	Atkinson Text—General plant anatomy, stem, leaf, seed, etc., 2 months. Work of plants, economic value, 2 months. Systematic botany, 1 month.	Work of plants.	Much of the last half month.
Waterloo, Iowa.	1	Stems and buds 3½ weeks, roots 1, seeds and germination 2½ weeks, leaves 2, cryptogams 2, flowers and classification 4, fruits 1, leaves 1.	Physiology and ecology.	One or two trips to study plant associations and adaptions.
Aurora, Ill. East Side H. S.	1	Tree study 5 weeks, leaves, stems, roots, seeds and seedlings, comprising their anatomy and physiology, 15 weeks. Second semester—Bacteria 2, algæ 3, fungi 4, lichens 1, mosses and liverworts 2, ferns 2, flowers 2, weeds 4 weeks.	Economic importance.	None except tree and flower study, which is more nature study than pure botany.
Macomb, Ill.	1	Seeds and seedlings 2 weeks, roots, stem, leaves, flowers, fruits, including functions and reactions to stimuli, 10 weeks, algæ 1, fungi 1, bryophytes 1, pteridophytes 1, gymnosperms 1, herbarium and classification 2 weeks.	Physiology of the higher plants.	None.
Waukegan, Ill.	2	Structure and functions of seed plants (except flowers), 8 weeks; evolution of plant kingdom, 12 weeks; ecology and economic value fruits and seeds, 4 weeks; local flora, classification and herbarium making, 12 weeks.	Fitness of plants to live in their environment.	Materials gathered. Most work in spring.
Streator, Ill.	1	Activities, structures and relations of leaves 4 weeks, roots 1, stems 3, flowers and fruits 2, seeds and germination 2 weeks, dependent plants and bacteria 2, evolution and plant breeding 2, principal families of higher plants 4.	Plant as a living working organism. Identification of common plants. Economic relations.	Ten to fifteen periods.

Rockford, Ill.		Fall flowers and weeds, 4 weeks; light relations of leaves, leaves and fruits of about 45 trees, shrubs and vines, 5 weeks; microscopic structure of leaves, algæ, physiology of green plants, 7 weeks; bacteria and other fungi, 3 weeks; winter condition of trees, stems, structure, 5 weeks; germination, soils, seed testing, foods in plants, 4 weeks; mosses, ferns, conifers, 3 weeks; spring flowers, plant families, cross pollination, plant breeding, plant societies, 9 weeks.	Recognition of common plants. Physiology and ecology of plants. Materials used in laboratory. Make course in botany foundation for agriculture as well as for biological science.	Several during fall and winter for materials for class-work, flower calendar, and leaf and fruit collections. Weekly trips in spring.

OUTLINES OF COURSES IN ZOOLOGY.

Jacksonville, Ill.	2	Insects, protozoa and other insects, typical invertebrates, vertebrates, 12 weeks each. Botany and zoology taught alternate years. General science first year.	Animals harmful to crops, orchards and gardens. Animals useful to man. Birds.	All materials studied in laboratory collected in field trips. Birds studied.
Detroit, Mich.	2	Insects,—collect and identify 6 or 7 orders; life histories and economic value of common forms, 6 to 8 weeks; protozoa annelida, mollusca, crustacea rest of semester. Vertebrates,—lower chordates, pisces, amphibia, reptilia, aves, mammalia, 4 to 5 weeks each on birds and frogs.	1. Same as in botany. Applying knowledge gained in study to everyday life.	So far as possible study habits and hibernations of all forms, also relations of insects and birds to plant life. Identify 40-50 birds.
Aurora, Neb.	1	1. Typical specimens of each of the group. 2. Identification of laboratory specimens. 3. Economic importance of animals.	1. Identification of laboratory specimens. 2. Economic importance.	None.
Quincy, Ill.	2	1. Arthropods to protozoa. 2. Fishes to man.	Life relations. That zoology is a subject that pertains to "here and now."	Seeing "our little brothers" in their respective homes. At least one period each week during good weather.
Ottumwa, Iowa.	2	Insects, mollusks, spider, crayfish, earthworm, nereis, clam, starfish, hydra, protozoa, fish, frog, bird in order.	Morphology. Economic zoology. Collect 50 insects.	At least a week for bird study in spring. Insect work in fall.
Sycamore, Ill.	1	Insects 3 months, protozoa and hydra 3 weeks, crayfish 2, worms 2, frogs 1, fish and birds 2, mammals 1, summary and evolution 1.	Relation to environment and man.	Two or three class trips. Individual class trips.
Paris, Ill.	1	Arthropods 6 weeks, annelids 2, Echinoderms 1, mollusca 2, glimpse of lowest forms chorates 6, survey of evolution 1 week.	Habitat and distribution. Relation to environment. Economic importance.	Student must collect specimens of forms used in laboratory.

Place.	Time sem.	Course.	Emphasis placed upon.	Field work.
Pontiac, Ill.	1	Insects 6 weeks, other phyla 8 weeks, and ecology of animals 4 weeks.		None. Pupils required to secure most of laboratory material.
Waterloo, Iowa.	1	Insects 8 weeks, crustaceæ 2, worms ½ week, mollusks 1, echinoderms and coelenterates 1, amphibia and fishes 2, birds 1½, and mammals 2 weeks.	Economic importance, adaptation, function.	One field trip in fall.
Kansas City, Mo.	2	Insects 6 weeks, protozoa 4, coelentrates 3, worms 3, mollusks 2, arthropods 4, echinoderms 1, chordates 12, insects 4 weeks.	Evolution and economic importance.	Students collect most of the materials used in laboratory; 3 or 4 trips in fall and spring.
Danville, Ill.	2	Insects 6 weeks, the cell, mollusca to protozoa, vertebrates. Special study of birds.	Well done note book work, careful dissection of a few types, environment influences.	Collect 50 insects, and report on their mode of life.
Lansing, Mich.	1	Each of chief group taken up. Two weeks to general principles.	Insects and mammals, economic value.	Collections of insects; outlines for field study by pupils; a few voluntary trips.
Aurora, Ill. (West Side)	2	Insects 2 months, other arthropods 2 months, echinoderms, coelentrates, protozoa 1 month, vertebrates rest of year.	Economic importance; habitat and adaptations; enemies and allies.	Collecting material by class for use in laboratory.
Indianapolis, Ind. Shortridge H. S.	2	Time, 5 double periods per week, 10 months. Insects 6 weeks, cell and protozoa 3, sponges and coelenterates 2, worms 3, crustaceæ 2, fishes 4, amphibia 3, reptiles 1, birds 5, mammals 5.	Principles of biology. Growth development, parasitism, adaptations, economic importance, conservation of natural resources.	About 10 field trips, much individual work, bird records by all and an insect collection. Each pupil takes one field problem on which he reports.
Ottawa, Ill.	2	Insects 6 weeks, other arthropods 2, mollusks 2, worms 4, lower groups 6, vertebrates 18 weeks.	Insects and vertebrates, structure and economic relations.	About 1 hour a week for eight weeks.
Kewanee, Ill.	1	Insects, mollusca, porifera, protozoa receive most time, others briefly.	Economic value of animal and its environment.	One or two collecting trips.
Cedar Rapids, Iowa.	2	Insects 6-7 weeks. Follow this protozoa to vertebrates.	Environmental conditions, economic value.	Field work on insects and birds. Six to 8 field trips.
Denver, Colo.	2	Beneficial and injurious insects 6 weeks. Brief survey of each phylum. Special attention to local fauna, animal characteristics, struggle for existence, life cycle, mimicry, development, communal life, etc.	Study of animals, not books. Fresh material.	One class makes field trip each week—large amount of living material brought in and kept in laboratory.

"PRACTICAL" WORK IN PHYSICS AND CHEMISTRY.

Place.	Physics.	Chemistry.
Menominee, Wis.	Pupils work out special topics,—city water works, sewing machine, automobile, steam engine, gas engine, fireless cooker, etc.	Girls study food chemistry, boys cement, bricks, iron, soil, etc.
Ottumwa, Iowa.	Practical application of everything taught emphasized. Practical problems given. Visits to power plants, etc.	Practical exercises—acid in vinegar, chemical tests of cloth fibers, baking powders, etc.
Jacksonville, Ill.	Emphasize industrial side by visiting different plants relating to our subject.	Use food tests, baking powders, fermentation, fertilizers, fire extinguishers, photography.
Minneapolis, Minn. North H. S.	Emphasize practical and everyday side of each subject as much as possible.	Experiments in miniature of commercial manufacture of certain chemicals. Test for purity of water, ores, making mirrors, bleaching, dyeing, photography, ice manufacture, etc.
Detroit, Mich.	Use laboratory experiments which have a practical bearing.	Use many experiments having practical application, as fermentation. Tests of food, carbon compounds, distillation of coal and its gases, soda manufacture, also ammonia and acids. Attempt to bring out practical bearing.
Ft. Wayne, Ind.	All laws of physics are illustrated by practical examples.	Very little. Kept busy trying to give a fair understanding of chemical laws and the necessary elementary facts.
Saginaw, Mich.	In laboratory we do not. The classes are shown the practical application of the subject whenever possible.	Not so as to interfere with the scientific development of the subject. However, we use illustrative material drawn from the experience of the pupil whenever possible. Expect to start a special course for girls.
Moline, Ill.	All illustrations are made to apply directly to the commonest things of life. All experiments are made practical so far as possible.	Only enough theoretical work is taken up to make our work an orderly arrangement. No practical application neglected.
Elgin, Ill.	Determination of brake horsepower of a motor; heat content of city gas; heating and ventilation of our school building; rate of consumption of gas by gas stove; cost of gas and electric lights; study of gas engines.	Testing of water for impurities, dyeing, bleaching, fermentation, preservatives, testing foods for nutrients.
San Francisco, Cal. Mission H. S.	Experiments mostly qualitative to inductively present principles, not discover them. Practical applications to everyday phenomena we consider very important.	Our practical work bears on the chemistry of everyday life and home. We aim to let this take the place of the usual methods with the metals.

Place.	Physics.	Chemistry.
Rockford, Ill.	We try to see the practical application in every topic.	Test milk for fats, sugar, water, skimming and dirt. Analyze such things as sausage, pickles, coal, soil, fertilizer, stock feed, paint, baking powder, cocoa, extracts, whisky, butter, ice cream, blueing, etc. Our aim is to teach practical chemistry.
Kansas City, Mo.	As much as possible, especially in mechanic electricity and heat.	A very considerable amount,—soaps, hard water, baking powder, soda biscuit, water classification—bleaching, photography, etc.
Indianapolis, Ind. Shortridge H. S.	The work is made more vital and practical by introduction of interesting experiments, bearing directly upon the pupil's experience in daily life. (List follows; two long for this table.)	We attempt to train pupils to think and apply while dealing with the facts and theories of chemistry. (Details of this course cannot be given in this table.)
Denver, Colo.	At least half the work has practical bearing; the aim always is to make use of the past experience of the pupil, but this is difficult in mixed classes of boys and girls on account of the great difference in the experience of the boys and girls.	The work in qualitative analysis is certainly practical and in addition there are occasional visits to the smelters, chemical works, gas works, etc. Examinations of milk, baking powders, water, etc.

that they should receive attention in this report, and these are domestic science and agriculture. First, then, we shall consider the case of the courses in domestic science. For data I shall use a paper which I read to this body at its meeting in 1910, in which I made a comparative study of forty-three Illinois high schools.

Of the forty-three schools listed in this report—schools taken at random—44 per cent have courses in domestic science. Of the nineteen schools having domestic science in their curricula, seventeen have these courses in the first two years of the course with no science preceding which could serve to prepare the way for such courses. One school has its domestic science courses in the third and fourth, where it is possible that there might be correlation with the pure sciences. One other school has general science in the first year, with domestic science in the first three years of the course; there might be correlation here. A few schools have domestic science running through the entire four years. There might be some correlation in these schools, but probably not, since there could be no correlation in the first two years. From the above, it must be concluded that there is practically no attempt at correlation of domestic science courses with other science courses.

In discussing the correlation of agriculture with other sciences in the ordinary high schools, I am compelled to use data for the most part collected by others, since there was too little time for me to get data from original sources when I took over this topic. My principal source of information is a report made by C. H. Robison, entitled "Agricultural Instruction in the Public High Schools in the United States." This is a very extensive study of the subject and a very valuable one (made in 1910).

However, before analyzing the data to be gathered from Mr. Robison's report, it will be well to give some attention to the schools of this State which have courses in agriculture. At DeKalb a year's work in agriculture is given in the first year, thus treating it as an introductory science. At Princeton, agriculture is offered in the second year as an alternative for botany and zoölogy. It is preceded in the first year by physiography. At Freeport, agriculture is offered as an extra study—called the "agricultural club"—during the first two years. A note adds that "the work in botany, zoölogy, physics and chemistry is made practical for the study of agriculture." At La Salle an elaborate four-year course is offered in which agriculture and manual train-

ing are made to work together toward the one end. Only two pure sciences are offered in the agricultural course, namely, botany and zoölogy in the third year, and chemistry in the fourth year. Thus horticulture precedes botany, while zoölogy is given coördinately with animal husbandry. Physics is evidently included in the agricultural courses under various heads, as soil physics in the first year and farm-mechanics in the manual training course of the second year. This course seems to be well worked out, but the place of zoölogy and botany in the third year seems to be unfortunate, if the work is to be useful in agriculture. Apparently there is little correlation attempted in Illinois schools, except at the Freeport school, though an external study of courses cannot, of course, be conclusive.

Turning now to the data obtainable from Mr. Robison, the only point which I shall attempt to make is that of the correlation of agriculture with other sciences. Is there any attempt at correlation, or are the courses in agriculture put in where most convenient, or, perhaps, put in the first year to attract students from the farm—as a sort of bait? Mr. Robison has data from about one-third of the high schools in the United States then giving agriculture in the curriculum—enough, as he says, to indicate the "current practice" of the schools. Out of 104 schools which give only one year to agriculture, 49 place it in the first year, which, of course, renders correlation with other sciences impossible. Thirty-one more schools place agriculture in the second year, in which case it is possible to precede it by physiography, a science with which agriculture has comparatively little in common. If we add these two classes of schools together, we find that in 80 out of 104 schools reporting there can be but slight correlation with other subjects. Using other data, we find that agriculture is preceded by physical geography in 72 out of 108 schools reporting; preceded by botany in 33 schools; by zoölogy in 5 schools; by physics in 16 schools, by physiology in 17 schools. By these figures it is seen that the studies most useful to agriculture are least likely to precede the subject.

It does not seem necessary to quote further. Probably the lack of some settled plan of correlating the work in science in these schools is no more than is to be expected, considering the fact that agriculture is but just beginning to get a foothold in the curricula of high schools. But the fact that domestic science is also uncorrelated with sciences which might contribute to it tends to show a lack of appreciation that one science might help

another—or a pure science help an applied science. We have no right to expect anything else, for the pure sciences themselves in the high schools, physiography, botany, zoölogy, physics, and chemistry, are each regarded and treated as entities having nothing in common. Each teacher puts into his department of science just what he pleases, with little or no regard to any other department. If between them all something fundamental is untouched, it is nobody's business. If this be true, and it cannot be successfully disputed, how could we expect a new science to be correlated with the older departments already in possession.

I cannot close my paper without some suggestions, hoping that they reach some sympathetic ears. My first suggestion is that when a new applied science such as agriculture is put into a curriculum, all interested in science in the school ought to be the ones to adjust it to its proper place and that the older departments ought to be correlated with the newcomer in such a way that what is already established in the school should contribute as much as possible to the new course. To be more explicit, why not let a general science course, or the physiography, botany, and zoölogy, contribute all they can to agriculture, and this can be a great deal; then agriculture can in its turn be made purely applied science, counting upon the help of other sciences to prepare the ground. The agriculture thus arranged would be of quite a different type from the mixed pure and applied science usually given. It would seem to be good business economy, to say nothing of educational economy, to let what is already established in the school do all it can, instead of running parallel courses—thus doubling the teaching and halving the size of the classes. Two years of agriculture rid of its pure science mixture should be sufficient if built upon two years of pure science in the first two years of the high school and correlated with the pure science of the last two years. If there can be but one year of agriculture, then it should be in the third or fourth year to make it most effective. This idea of putting agriculture in the first year is on a plane with the placing of stenography or bookkeeping in the first year—a bait to get the boy or girl into the high school and unworthy of an educational program. Studies should be placed where they belong in a consistent course. If the school is turning out self-reliant boys and girls, that is sufficient bait and the only inducement worthy of a school.

I cannot help thinking that in all this talk about practical courses, vocational training—continuation schools, industrial

schools—there is danger of losing sight of certain fundamentals in education. Ought the boy or girl to be educated for a certain predetermined groove in society? Are we not in danger of doing this very thing, and is this not an effective method of perpetuating class distinctions? Is not such a course contrary to the well-being of a democratic form of government? These are things to be thought of seriously.

THE RELATION OF PURE SCIENCE TO APPLIED SCIENCE IN THE AGRICULTURAL HIGH SCHOOL IN THE UNITED STATES.

J. T. JOHNSON.

During the year 1910 there were more than 630 secondary schools offering instruction in agriculture. Of this number there were more than 80 agricultural high schools, and 29 public high schools which received state aid. The committee thought it to be advisable to limit the investigation to those schools which are distinctively of the high school type.

This report endeavors to consider the following questions: What is the organization of the courses of science in the agricultural high school? What pure science, if any, is given? What is the position of pure science in the courses in agriculture? If no pure science is given in distinct courses, how is the necessary foundation of pure science given?

Whatever may be the distinction between pure science and applied science, the pure sciences referred to in this discussion are assumed to be botany, zoölogy, physics, chemistry, physiology, hygiene, physiography, biology, and bacteriology.

To secure data as recent and reliable as possible, letters were sent to each of the Superintendents of Public Instruction, and to each of the agricultural high schools reported to the Bureau of Education, Washington, D. C. At present replies have been received from thirty-six States, and one each from Hawaii and Porto Rico, making thirty-eight replies from officers of public instruction. Similarly, letters have been received from forty-seven high schools of the agricultural type.

The following questionaire was sent to the agricultural high schools:

WESTERN ILLINOIS STATE NORMAL SCHOOL
MACOMB
OFFICE OF PRINCIPAL: JOHN E. MCGILVREY

January 15, 1912.

Dear Sir: The State Academy of Science of Illinois has asked me to investigate and report on the Agricultural High School of the United States at its regular meeting in February. I shall be greatly aided if you will forward me a catalog of your course of study, and answer the following specific questions at your earliest convenience, since the time is very short.

Hoping to be able to favor you at some time, I am,

Very truly yours,

J. T. JOHNSON,
Department of Agriculture.

Exact name of school.....
When established.....
Name of head.....Title.....
Number of buildings.....Cost.....
Number of acres of land.....Value.....
How supported.....
Amount of appropriation each year.....
Amount of private, or public, contributions.....
Number of years of work in high school.....
Number of students.....Boys.....Girls.....
Number of months school is in session.....
How many weeks are the following subjects taught (If not taught leave space blank): Physics.....Chemistry.....Botany.....
Zoölogy..... Physiology..... Hygiene.....
Bacteriology..... Physiography..... Biology.....

Somewhat more matter was requested than was implied in the question under investigation, but inasmuch as the data would bear indirectly upon the agricultural high school it was thought advisable to request it. In some instances the accessory data helped to determine the type of school when, in a few instances, catalogs and programs of study could not be furnished because they were either out of print or to date none had been printed.

According to *name* the types are easily distinguished, and may be listed in the following manner: State, County, Congressional District, Supreme Court Judicial District, Public High Schools receiving State aid, and Privately endowed. But according to the *program* of work, and which is more important in the purpose of the State Academy of Science, the types are not so easily distinguished, due to the confusion in the content of subject matter, and the methods of presentation. It is probably too early to assume that the agricultural type of high school is differentiated, but whatever the assumption, the type, or types, do not seem to have appeared from the incomplete reports at hand. Many of the agricultural high schools could be easily mistaken for the accepted high school were it not for the name.

In order that the conditions may be made intelligible in this brief report, a few summaries are offered from the letters re-

ceived. There are 114 agricultural high schools reported by the Superintendents of Public Instruction. Fourteen States are reported to have agricultural high schools, as indicated by the letters from the superintendents, and four other States were reported by the principals in the schools, making a total of eighteen States. There are twenty-two States reported to have no agricultural high school. Recent laws will require a few States to teach agriculture next year. Pennsylvania will require the subject to be taught in every township high school.

In comparing the number of pure sciences taught in the schools it was observed that two schools, only, offered all. The schools referred to are the National Farm School, Pennsylvania, and the School of Forestry, North Dakota. No school was found which did not offer at least one of the pure sciences. The Dunn County Agricultural High School, Wisconsin, offered one subject only, which is Physiology, covering a period of eight weeks. These schools represent the extremes. The others are tabulated as follows:

3	schools	offer	2	pure	sciences.
9	"	"	3	"	"
6	"	"	4	"	"
14	"	"	5	"	"
6	"	"	6	"	"
4	"	"	7	"	"

The following tabulation shows the rank of the separate sciences as they are found in the various courses of study:

Chemistry appeared 40 times.
Physics appeared 37 times.
Botany appeared 36 times.
Physiology appeared 27 times.
Physiography appeared 18 times.
Hygiene appeared 18 times.
Zoölogy appeared 15 times.
Bacteriology appeared 12 times.
Biology appeared 7 times.

Chemistry, physics, and botany rank essentially the same, with chemistry slightly in the lead. In the entire list, chemistry is the most favored, and biology the least. The above list of ranks is based upon qualitative values, and to make the comparison more truthful the following tabulation is based upon quantitative values, where the number of weeks taught is considered. Totals are expressed in each instance.

Chemistry is taught 1,225 weeks.
Physics is taught 1,200 weeks.
Botany is taught 770½ weeks.
Physiology is taught 629½ weeks.

Physiography is taught 506 weeks.
Hygiene is taught 367 weeks.
Zoölogy is taught 294 weeks.
Bacteriology is taught 238 weeks.
Biology is taught 234½ weeks.

The quantitative basis for ranking places chemistry in the lead also, and tends to group chemistry and physics separately from botany, since there is a margin of 430 weeks between the lowest, botany, and the next, physics. The order of the ranking is the same for the pure sciences, whether placed on the qualitative or quantitative basis. The quantitative ranking merely serves to accentuate the preference for chemistry and physics. The greatest length of time devoted to any one science is 72 weeks, for chemistry; and the same, 72 weeks, is found also for physics. The greatest length of time devoted to botany is 40 weeks. The shortest length of time is 3 weeks, for zoölogy, and the next is 4 weeks, for hygiene.

The length of the course of study varies, and it would be unwise to assume that each of the agricultural high schools has a four-years' course, which fact is revealed in the comparison below:

1 school has a course of 5 years.
26 schools have a course of 4 years.
9 schools have a course of 3 years.
8 schools have a course of 2 years.

Nearly 63 per cent of the schools have a course of study under four years in length.

The length of the school year varies from twelve months to six months.

1 school continues for 12 months.
1 school continues for 10 months.
33 schools continue for 9 months.
7 schools continue for 8 months.
2 schools continue for 6 months.

About 25 per cent of the agricultural high schools have a school year fewer than nine months in length.

The above summarizations are transmitted from data collected from original sources with the hope that the members of the State Academy of Science may have an adequate perspective of the pure sciences in the authorized agricultural high schools in the United States.

Necrology

IN MEMORIAM: FRED LEMAR CHARLES.

ELLIOT R. DOWNING.

Fred Lemar Charles was born at Aurora, Illinois, November 15, 1874. His father was then County Superintendent of King County; his mother, a woman of culture, of sensitive and poetic temperament. He attended school in the graded schools and high school of Austin, Illinois, then went on to Northwestern University, where he graduated, and later attended the University of Chicago, from which institution he received his master's degree. Two summers were spent at Woods Hole, Massachusetts, and it was while we were there together that the author of this sketch formed that friendship for Mr. Charles which lasted until the time of his death, as did all friendships with this man. When once you were taken into the circle of his intimates, the attachment was bound to be a life-long attachment.

He began his teaching in Lakeview High School, then went to the Northern Illinois State Normal at DeKalb, in which institution he remained for ten years, 1899-1909, as head of the Department of Biology. He was then called to the University of Illinois, as Assistant Professor of Agricultural Education. In January, 1910, he assumed the editorship of the Nature-Study Review, which magazine he continued to edit until his death.

In 1904 he married Miss Elsie Davis, and shortly afterwards built the house in DeKalb which was their home, and the home of their two children, for several years. Mr. Charles' home life was ideal, his devotion to his family was untiring, and in his home he found his largest enjoyment.

He was a man of sterling worth, lovable and loyal, conscientious and upright, brilliant and determined. He was sensitive to a degree, artistic and poetic, a man who was not only a student of nature, but a thorough lover of nature. I quote from Professor W. C. Bagley:

"But there was another side to his life, and there was another type of influence that he exerted over those who knew him well. When a man is in almost constant physical pain; when he feels that he is gradually but surely losing his grip on the threads of life; and when, under this condition, he can clinch his teeth as Charles did, and work on steadfastly while only the great dark looms up before him; when he can mingle with his friends and live in close association with his fellow-workers without once re-

vealing, save perhaps through the indirect expressions that no man can inhibit, the physical and mental torture that he is undergoing; then he has set a standard that deserves the name of achievement, if any conquest in this life deserves that name."

As a teacher he was equally successful in handling children and advanced students. He not only succeeded in inspiring his students with a zeal for the subject matter that he dealt with, but he also gave them an enthusiasm for the high ideals that were always his, and imparted also some of that spirit of self-sacrificing devotion that ruled his own life. He was skillful in planning, and wise in execution, as is evidenced by the successful organization of the mass of chaotic material which he had to arrange in formulating a course in elementary agricultural education. His ability is shown again in his work as an editor, and a leader in nature study. I quote from B. M. Davis, President of the American Nature-Study Society:

"Those who were fortunate in knowing Professor Charles keenly feel the personal loss, and those who knew of him through his educational activities, particularly in the cause of nature study, will miss his leadership.

"The American Nature-Study Society owes much to him. He was interested from its beginning as a member and as an officer. As editor of this magazine he made many sacrifices in its behalf. He did not spare himself, but thought only of its success. The measure of this success is known to all its readers."

I am happy to have this opportunity to express my appreciation of, and regard for, Fred L. Charles, as a student of nature, a teacher of her ways, an inspiration to the student body with which he came in contact, a loyal friend, a royal man.

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A complete Table of Contents for this volume is presented on pages 3 and 4; a List of Illustrations appears on page 5. A very brief index is scarcely more than a duplication of the Table of Contents, and List of Illustrations, and it has been thought unwise to print an exhaustive index such as would cover all details in a volume of the nature of this one.

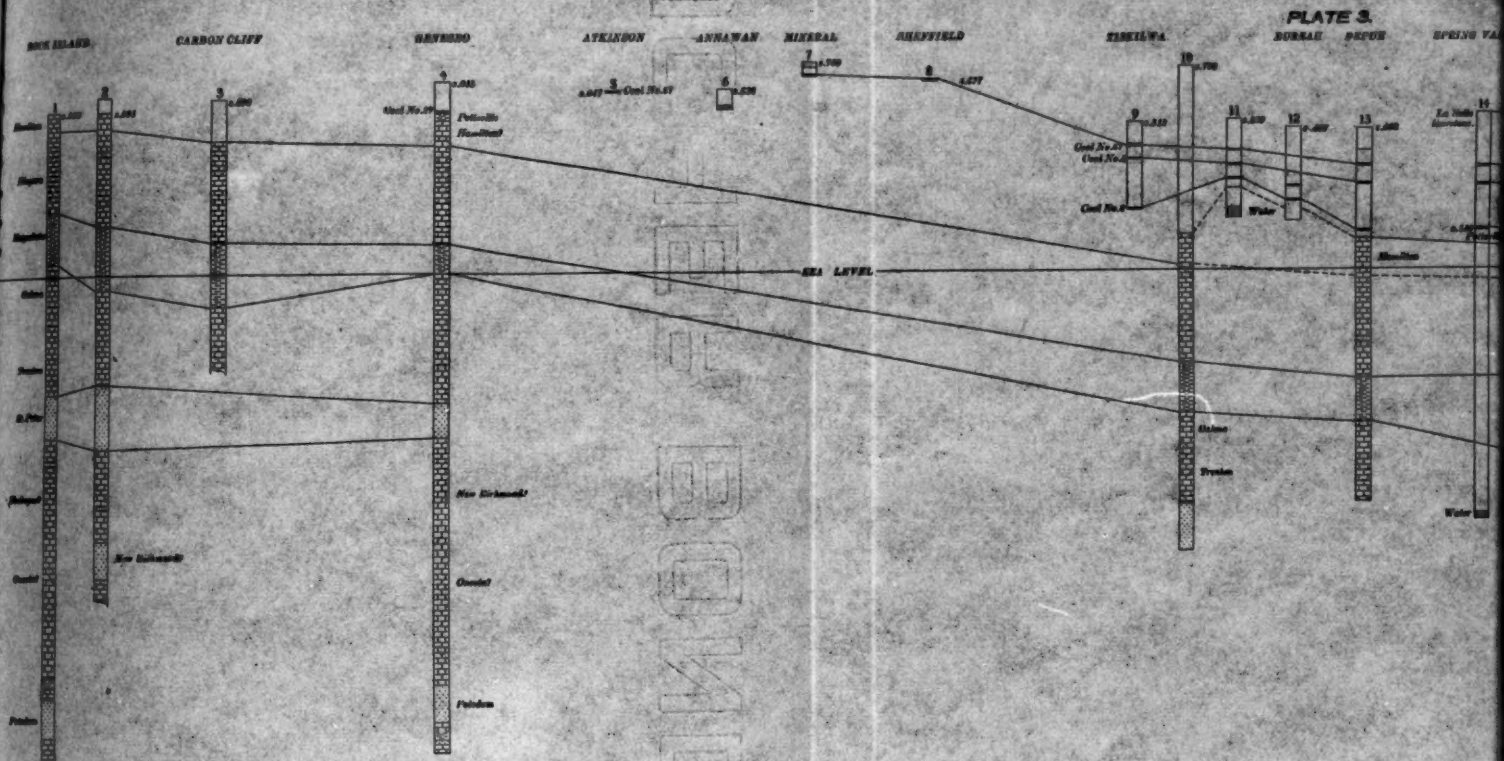
PLATE 3.
ROCK ISLAND
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DEPUE
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Coal No.2
Coal No.3
Coal No.4
Coal No.5
Coal No.6
Coal No.7
Water
Shales
Sandstone
Limestone
Fireclay
Pottsville Conglomerate
New Richmond Sandstone
Oneota Limestone
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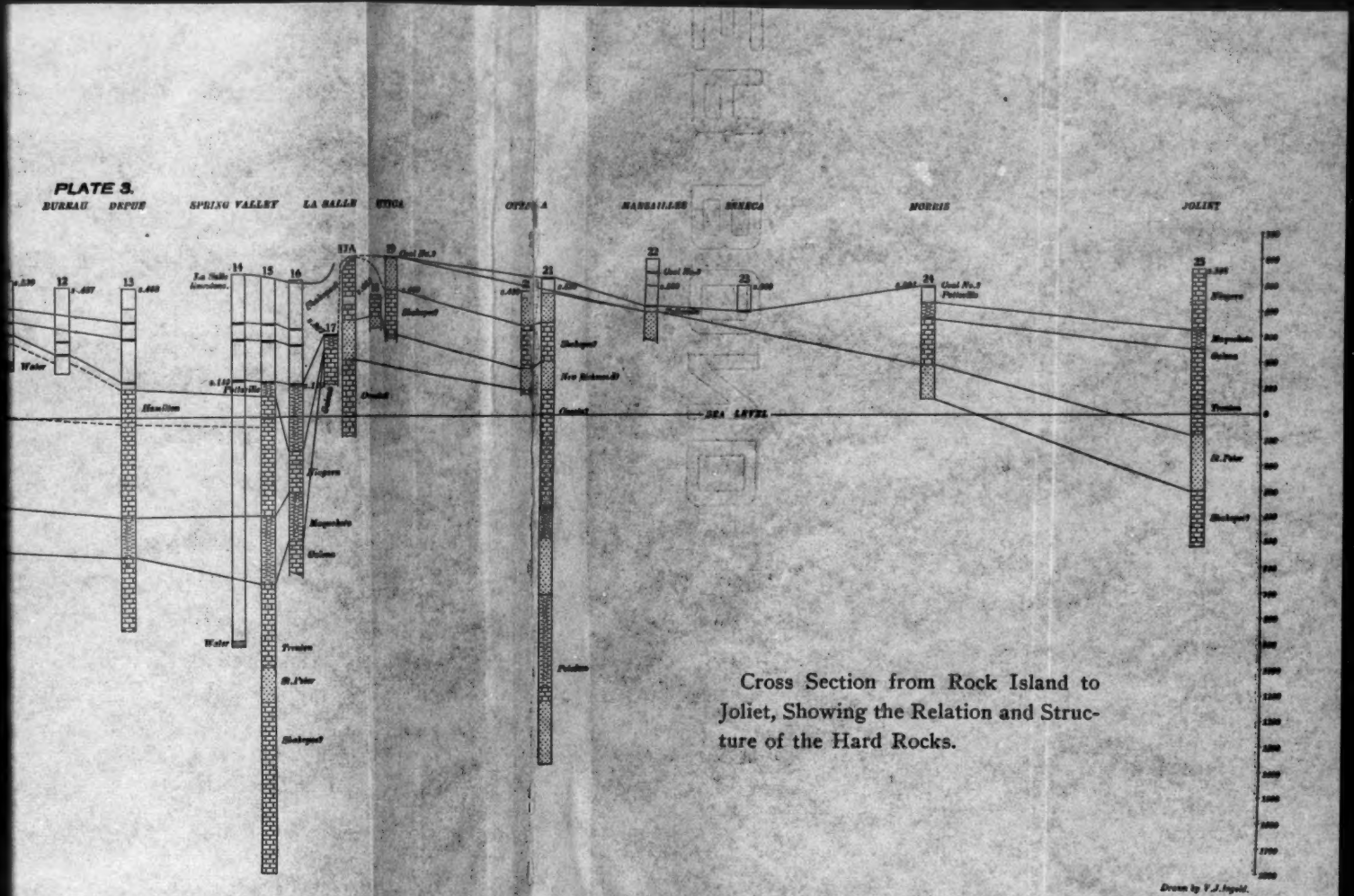

Cross Section from Rock Island to Joliet, Showing the Relation and Structure of the Hard Rocks.